ISSN 0377–9335

Vol. 34 September 2009 No. 3

CONTENTS

Continued on back cover

Centre for Arthropod Bioresources and Biotechnology (CABB),
University of Kerala, Kariavattom, Trivandrum, India 695 581

ENTOMON

ENTOMON is a quarterly journal of the Association for Advancement of Entomology issued in March, June, September and December, devoted to publication of research work on various aspects of insects and other arthropods.

Address MS and all editorial correspondence to Managing Editor, ENTOMON, Centre for Arthropod Bioresources and Biotechnology (CABB), University of Kerala, Kariavattom, Trivandrum 695581, India.

SUBSCRIPTION RATES

Annual subscription for Institutions: Rs. 2000.00 (in India); US$ 250 (Air Mail)
Annual subscription for individuals: Rs. 300.00 (in India); US$ 100 (Air Mail)

1. All remittance to the Journal or Association should be sent to the Secretary-Treasurer of the Association by Bank Draft only, A/c payee in favour of the Association for Advancement of Entomology, payable at Kariavattom.
2. Requests for replacement copies of ENTOMON in lieu of numbers lost in transit, should reach the Secretary-Treasurer not later than three months after the date of publication of the number.

ENTOMON is covered in the following abstracting/indexing journals: *Chemical Abstracts, Review of Applied Entomology, Science Citation Index* and *Current Contents/Agriculture, Biology* and *Environmental Sciences, Biological Abstracts, Entomology Abstracts* and other relevant abstracts. *Referativny Zhurnal* and *Current Advance in Biological Sciences* and *New Entomological Taxa*.

ENTOMON **34(3):** 123–135 (2010)
Article No. ent.34301

Intraspecific variations in three vector species of *Culex vishnui* subgroup (Diptera: Culicidae) based on male genitalia

Sagandeep Kaur[1], Monika Airi*[2] and P. K. Tewari[2]

[1]*Department of Zoology, DAV College, Sector 10, Chandigarh, Punjab, India*
Email: shagan_deep@hotmail.com
[2]*Department of Zoology, Panjab University, Chandigarh, Punjab, India*
Email: monika_airi@yahoo.co.in

ABSTRACT: The three vector species of Japanese encephalitis viz., *Culex vishnui* Theobald, *Cx. pseudovishnui* Colless and *Cx. tritaeniorhynchus* Giles were found to show variations both in morphology and male genitalia. Variations occur on the lateral plate of phallosome of male genitalia with respect to the number and shape of finger-like structures on the inner division, sternal spine, mesal spine, lateral basal process and on the apical sternal spiculate portion. In addition to this, new morphological variations in other body parts were recognized.

KEYWORDS: *Cx. vishnui*, *Cx. pseudovishnui*, *Cx. tritaeniorhynchus*, intraspecific variations, male genitalia

INTRODUCTION

Culex vishnui subgroup contains three important vectors of Japanese Encephalitis (JE) in India. These are *Culex vishnui* Theobald, *Cx. pseudovishnui* Colless and *Cx. tritaeniorhynchus* Giles, of which, the last one been incrimated as a major vector of JE in this country. All the three species are extremely similar in morphology and male genitalia and hence create confusion in their correct identification. The presence of intraspecific morphological variations further enhances the problem of identification and also leads to overlapping of the species with each other.

The present studies on the subject have revealed that all the three JE vectors show intraspecific variability both in external morphology and male genitalia. Previous workers like Reuben (1969), Sirivanakarn (1975, 76), Tandon *et al.* (1995) also noted some morphological variations in various body appendages but they did not observe

*Corresponding author

them in male genitalia. The present communication records the occurrence of these variations in the male genitalia with respect to the various parts of lateral plate of phallosome i.e. shape of apical sternal spiculate portion, number and shape of finger like processes on the inner division, sternal spine, mesal spine and lateral basal process of phallosome. These variations were examined after carefully separating the lateral plate of phallosome from rest of the genitalia and then observing the minute details of each part. In addition to the variations in male genitalia, some of the new variations were noted in the external morphology of the three species.

MATERIALS AND METHODS

Adults of *Culex* spp. were collected from various habitats like cattle sheds, human dwellings, mixed dwellings and open vegetation from the state of Punjab and Union Territory of Chandigarh, India.

As per previous records (Colless, 1957; Bram, 1967; Sirivanakarn, 1976), the larvae of *Culex vishnui* and *Cx. pseudovishnui* are diagnostic and do not show any kind of variation, whereas two types of larvae of *Cx. tritaeniorhynchus* have been reported. In view of this, the egg rafts and larvae of *Cx. tritaeniorhynchus* were collected in plastic containers and brought to laboratory for further rearing.from ponds having aquatic vegetation. They were found under submerged aquatic plants like *Eichhornia*, water lily, etc in ponds. The identification of larvae and adults of the three species was done using the key of Reuben *et al.* (1994). The adults were individually examined under the binocular microscope for studying the variations. The material examined comprised 69 species of *Cx. vishnui*, 116 of *Cx. pseudovishnui* and 272 of *Cx. tritaeniorhynchus*.

The genitalia were prepared by the method described by Siverly and Shroyer (1974). The genitalia was kept in boiling 10% KOH for 2–3 min and then transferred to water. After 4-5 washings in water it was placed on a slide in 95% alcohol for 2 min, followed by xylene for 5 min and mounted in canada balsam. For phallosome preparations, the genitalia was further dissected. The particular permanent genitalia slide, of which the phallosome preparation was to be made, was dipped in xylene for 30–40 min. The coverslip was removed gently from the slide and genitalia dissected on the slide itself with fine needle under binocular microscope. The lateral plate of phallosome was separated and mounted in desired orientation in canada balsam.

The intact genitalia slides were photographed at 25x magnification whereas the phallosome preparations were photographed at 40x magnification, which were further substantiated by camera lucida diagrams. The mean and Standard Deviation of the lengths of the structures were worked out. The terminology for naming various parts of genitalia was adopted from Sirivanakarn (1976).

RESULTS AND DISCUSSION

Culex tritaeniorhynchus Giles

The taxonomic observations of *Culex tritaeniorhynchus* reveal following types of variations in its morphological characteristics.

TABLE 1. Length of various parts of male genitalia of *Culex tritaeniorhynchus*

Part	Length in mm (Mean ± SD) Normal	Variant
1st process	0.865 ± 0.204	1.023
2nd process	0.690 ± 0.187	0.847
3rd process	0.548 ± 0.185	0.709
4th process	0.341 ± 0.062	0.601
Mesal spine	0.60 ± 0.199	0.578

Head: Decumbent scales of vertex predominantly golden or golden brown. Very few scales present on ventral surface of proboscis, therefore, speckling absent. However, in some individuals, pale scales on ventral surface are abundant which give it a speckled effect. Pale scales on proximal of median ring of proboscis either present or absent.

Thorax: Colour of scales on the mesonotum varies from light brown, chestnut brown to blackish brown. Fossal area with or without reddish tinge of golden scales. Scales on scuttellar lobes can be whitish, pale yellowish or golden.

Legs: Anterior surface of fore and mid femora ochre brown or dark brown. Speckling of pale and dark scales either well contrasted or poorly contrasted. Apical bands on tarsomeres usually present but sometimes these are found to be absent.

Abdomen: Elongated basolateral pale spots of abdomen may be present or absent on last 2-3 segments. Abdominal terga with basal bands, which may be narrow or wider in the middle.

Male genitalia: (Fig. 1a, bi, bii) Phallosome — Apical portion of inner division of lateral plate expanded distally into a triangular lobe. Finger-like processes (FLP) of inner division 4, gently curved and shorter in length with average length, in mm, of 0.865, 0.69, 0.548 and 0.341 for 1st, 2nd, 3rd and 4th process, respectively (Table 1). Mesal spine (MS) slender (0.6 mm) and curved. Lateral basal process (LBP) small and narrow.

A single variation (Fig. 1 ci, cii) on the lateral plate of phallosome has been observed: FLP 4, sharply curved and longer with the length of 1.023 mm, 0.847 mm, 0.709 mm and 0.601 mm, respectively, of 1st, 2nd, 3rd and 4th process. Mesal spine stout (0.578 mm). Lateral basal processes broad and thick.

Taxonomic discussion

The variant population of *Cx. tritaeniorhynchus* has been reported for the first time by Colless in 1957, who described it under the name *summorosus*, as subspecies of *Cx. tritaeniorhynchus*, on the basis of two characters i.e. the length of larval siphon and size of finger like processes on the lateral plate of phallosome of male genitalia. In pure *Cx. tritaeniorhynchus* the larval siphon is short with sides parallel and apex truncate and FLP of phallosome weekly developed. In the variant species the siphon is slender, considerably longer and the FLP strongly developed, comparatively longer and sharply

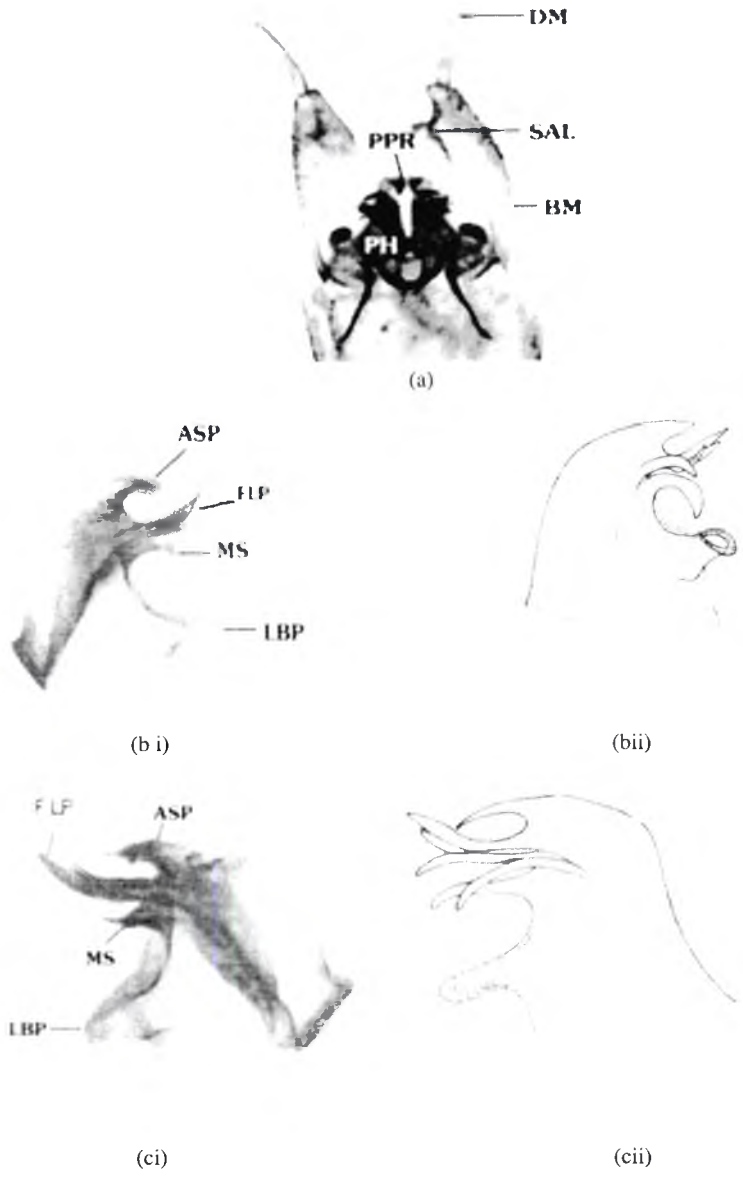


FIGURE 1. Male genitalia of *Culex tritaeniorhynchus*. a, whole view; bi & bii, photograph and drawing of phallosome; ci & cii, photograph and drawing of lateral plate of phallosome of variant.

PH — Phallosome; FLP — Finger like process; MS — Mesal Spine; SS — Sternal Spine; ASP — Apical Sternal Spiculate Portion; LBP — Lateral Basal Process; BSP — Basal Sternal Process; DM — Distimere; SAL — Sub Apical Lobe; BM — Basimere; PPR — Paraproct.

curved. Though Barraud (1934) did not notice the occurrence of this variant form in India his studies strongly indicate the existence of these variants in Indian populations as in his description of *Cx. tritaeniorhynchus* he described the larva of the variant and the adult of typical *tritaeniorhynchus*. Bram (1967) mentioned the presence of both these forms in Thailand and he regarded them as intermediates. He denied the status of *summorosus* as a separate subspecies. Reuben (1969) while redescribing the species of *Cx. vishnui* subgroup did not make any mention of the morphological variant populations of *Culex vishnui*, *Cx. pseudovishnui* and *Cx. tritaeniorhynchus* in Southeast Asia. Sirivanakarn in 1976 followed Bram in recognizing *summorosus* as a variant population as he could not find any significant difference in any of the developmental stages or adult. So, he treated *Cx. tritaeniorhynchus* as a single variable species. During the present studies both pure and the variant form of *Cx. tritaeniorhynchus*, based on the characters similar to those described by Colless (1957), have been found in the populations of this species from Chandigarh (India) and surrounding areas.

Culex vishnui Theobald

Culex vishnui has been found to be an extremely variable species with respect to scale coloration on various body appendages.

Head: Vertex with upright forked scales usually all dark but sometimes with a distinct patch of rather pale ones, these vary from pale brown, dull straw to golden. On the proboscis, pale scales frequently scattered over dark area but sometimes these may be absent. Proboscis usually light to heavily speckled on its basal part and less frequently on apical part but speckling absent in some specimens. Thus, speckling on apical and basal part of proboscis either present or completely absent. Occasionally, pale band on proboscis extends basally and pale scales form a continuous pale area on the underside of proboscis.

Thorax: Scutum of typical *vishnui* with predominantly pale beige to dull straw scales in contrast to predominantly brownish among majority of variant populations.

Abdomen: Abdominal terga sometimes with apical scaling in addition to basal pale bands; may or may not form triangular areas of pale bands. Segment I, with a patch of either dark scales or white or both. Elongated basolateral pale spots either present on all the segments or only on last 2 segments. Sterna may be having same pattern of basal bands as on terga but sometime, it is entirely pale.

Male genitalia: (Fig. 2 a, bi, bii) Phallosome — Inner division of lateral plate with apical tergal crown of 3 or 4 finger-like processes, the most mesal process longest and rest gradually shorter. This character has been observed in almost all the populations studied and hence can be treated as a stable character. Length of inner-most two processes does not vary; however, majority of the variations start from the 3rd process onwards. In normal male the 3rd process is shorter (0.487 mm) than the 4th (0.58 mm) and is approximately equal to the length of mesal spine (0.485 mm) (Table 2). The average length of sternal spine is 0.625 mm in the male genitalia of normal *Cx. vishnui*.

Intraspecific variant populations on the basis of male genitalia are:

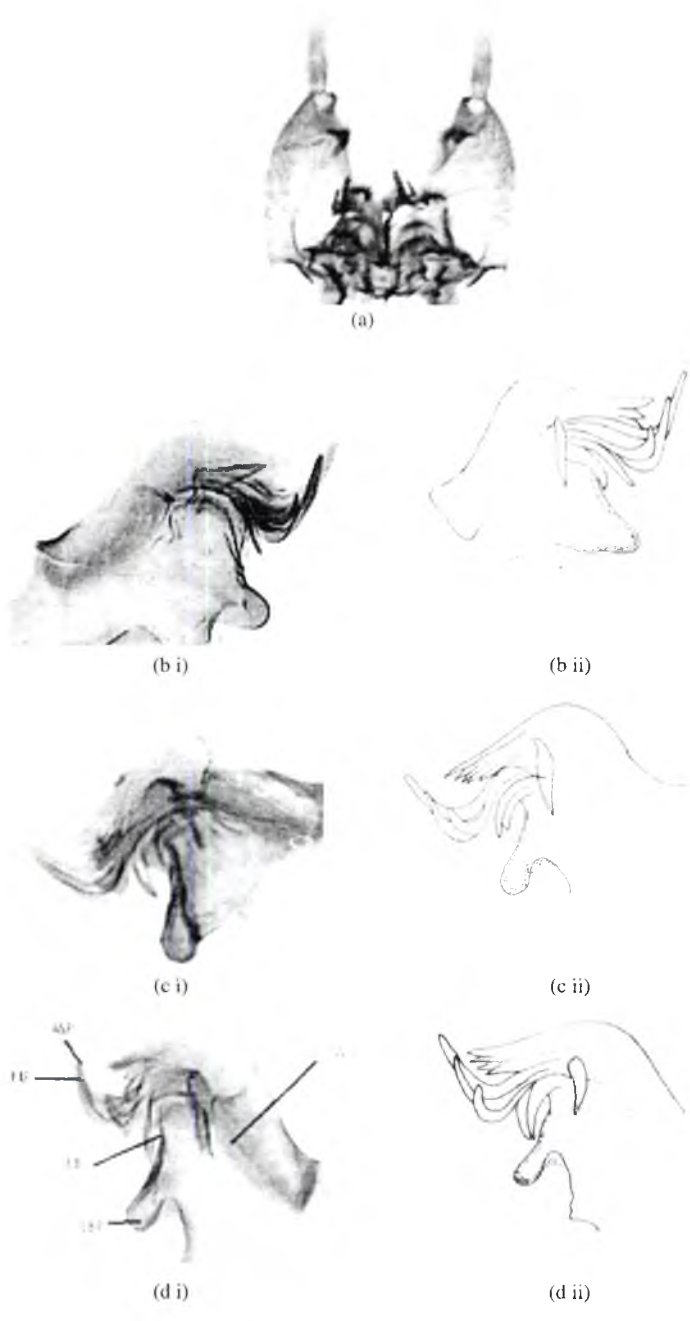


FIGURE 2. Male genitalia of *Culex vishnui*. a, whole view; bi & bii, photograph and drawing of phallosome; ci & cii to gi & gii, photograph and drawing of lateral plate of phallosome of variants I to V.

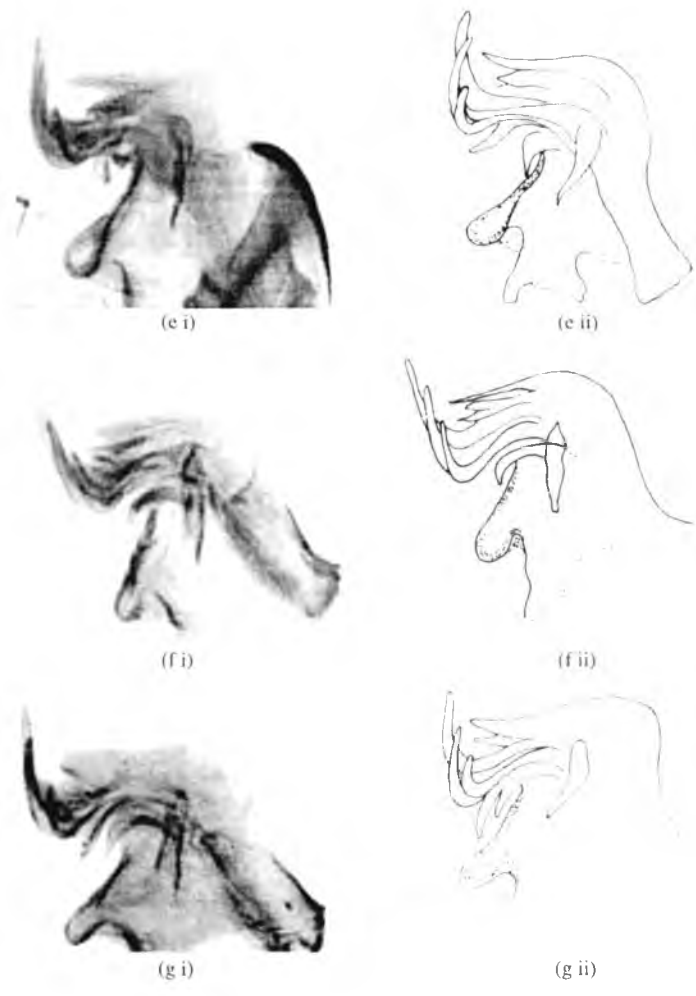


FIGURE 2. Continued.

TABLE 2. Length of various parts of male genitalia of *Culex vishnui*

Part	Length in mm (Mean ± SD)					
	Normal	Variant I	Variant II	Variant III	Variant IV	Variant V
1st process	0.965 ± 0.151	1.192	1.087	1.120	1.287	1.251
2nd process	0.745 ± 0.052	0.826	0.964	0.826	0.987	0.898
3rd process	0.487 ± 0.057	0.537	0.712	0.714	0.730	0.632
4th process	0.580 ± 0.073	0.567	0.759	0.520	—	0.744
Mesal spine	0.485 ± 0.066	0.472	0.522	0.267	0.517	0.589
Sternal spine	0.625 ± 0.066	0.966	0.792	1.035	0.740	0.729

Variant I

(Fig. 2ci, cii) : Number of FLP 4, 3rd process short but longer than the normal, measuring 0.537 mm and stout (0.53 mm), 4th again short (0.567 mm) but longer and less stouter (0.336 mm) than 3rd (Table 2). MS shorter than 3rd process i.e. 0.472 mm in length. SP longer (0.966 mm) than normal, thin and blunt-tipped. Margin of ASP irregular. LBP less broad and well defined.

Variant II

(Fig. 2 di, dii): Number of FLP 4, 3rd and 4th FLP moderately long (0.712 mm and 0.759 mm, respectively) and less stout (0.327 mm, 0.225 mm) (Table 2). MS longer (0.522 mm) than the mesal spine of normal, but shorter than the 4th process. SS (0.792 mm) longer than the normal but shorter than the variant I. Margin of ASP irregular. LBP moderately thickened.

Variant III

(Fig. 2 ei, eii): Number of FLP 4, 3rd process long (0.714 mm) but 4th one short (0.52 mm) (Table 2). MS very short (0.267 mm), even shorter than 4th process. SS exceptionally long measuring 1.035 mm (longest of all variants) and pointed. Margin of ASP bifurcated. LBP less thickened.

Variant IV

(Fig. 2 fi, fii): Number of FLP only three, 3rd process long (0.73 mm) and thick (0.5 mm) (Table 2). MS also long (0.517 mm) but not pointed. SS (0.74 mm) longer than the normal less broad with tip not well defined. Margin of ASP irregular. LBP broad and thick.

Variant V

(Fig. 2 gi, gii): Number of FLP 4, 3rd process proportionately more broad (0.533 mm) as compared to its length (0.632 mm), 4th long (0.744 mm) and thin (0.185 mm) (Table 2). MS pointed and shorter (0.589 mm) than 4th process. SS again long i.e. 0.729 mm in length with its tip pointed. Margin of ASP irregular. LBP long, narrow and well defined.

Taxonomic discussion

Cx. vishnui being highly variable species, had its taxonomic status confusing and highly controversial until Reuben (1969) redescribed all the developmental stages from reared specimens collected from the type locality in Madras, south India. Sirivanakarn (1976) followed Reuben (1969) in synonymizing *Cx. annulus* Theobald with *Cx. vishnui* and included all Southeast Asian forms previously attributed to *annulus* by Colless (1957), Delfinado (1966) and Bram (1967).

The present study confirms that *Cx. vishnui* is an extremely variable species. It

varies with respect to the colouration of the upright scales on vertex and presence or absence of pale scales, speckling as well as width of the pale band on proboscis. The variation in pale band width has been reported earlier also by many workers (Colless, 1957; Delfinado, 1966; Bram, 1967; Reuben, 1969; Tandon *et al.*, 1995). The typical *vishnui* has pale beige to dull straw scales on its scutum, whereas these are brownish in majority of variant populations. Reuben (1969) also noticed the same pattern of scutal scales; however, Bram (1967) reported that the scutum and scutellum are covered with dense variable dark brown and golden scales. Bram (1967) and Reuben (1969) reported the presence of 3 or 4 strong pigmented teeth on the phallosome which correspond to the finger like processes as indicated by Sirivanakarn (1975).

It has been observed in this study that five types of intraspecific variant populations exist in *Cx. vishnui* with respect to variations in male genitalia based on the size of finger like processes on the inner division of phallosome, shape of apical SSP, MS, SS and LBP. The status of these variant populations, particularly variant population III, is of interest for further study. This population shows significant differences with respect to the shape of ASP and the size of SS.

Culex pseudovishnui Colless

The following variations were noted in *Cx. pseudovishnui*.

Head: Female palps entirely dark or with pale scales at terminal segment. The colour of vertex scales vary from dull straw to white, pale or dull cream. The pale band on proboscis usually narrow but sometimes broad. Speckling of pale scales on the proboscis either present or absent.

Thorax: Colour of scales on mesonotum varies from pale yellow to cream or white. Golden scales present around prescutellar space instead of dark as studied by Sirivanakarn (1976).

Abdomen: Abdominal segment I with tergum having a patch of brown scales in center and white on sides, however, only black coloured streak observed in many specimens, segments II -VII sometimes with triangular basal bands. Abdominal sterna with same pattern of basal bands as on terga. Apical scaling also found in addition to basal bands in some populations.

Male Genitalia: (Fig. 3 a, bi, bii) Phallosome — Number of FLP on the inner division 3–4 similar to those found in *Cx. vishnui*; innermost two processes long while, the remaining two short, again as in *vishnui*; 3rd and 4th process short and stout with average length of 0.47 mm and 0.37 mm in almost all the studied populations (Table 3). The average length of mesal spine is 0.54 mm and that of sternal spine is 0.55 mm. FLP of *Cx. pseudovishnui* differ from those of *vishnui* slightly on the basis of size of first and second processes which are large in *vishnui* as compared to those in *pseudovishnui*. Margin of ASP portion irregular.

Intraspecific variant populations on the basis of male genitalia are:

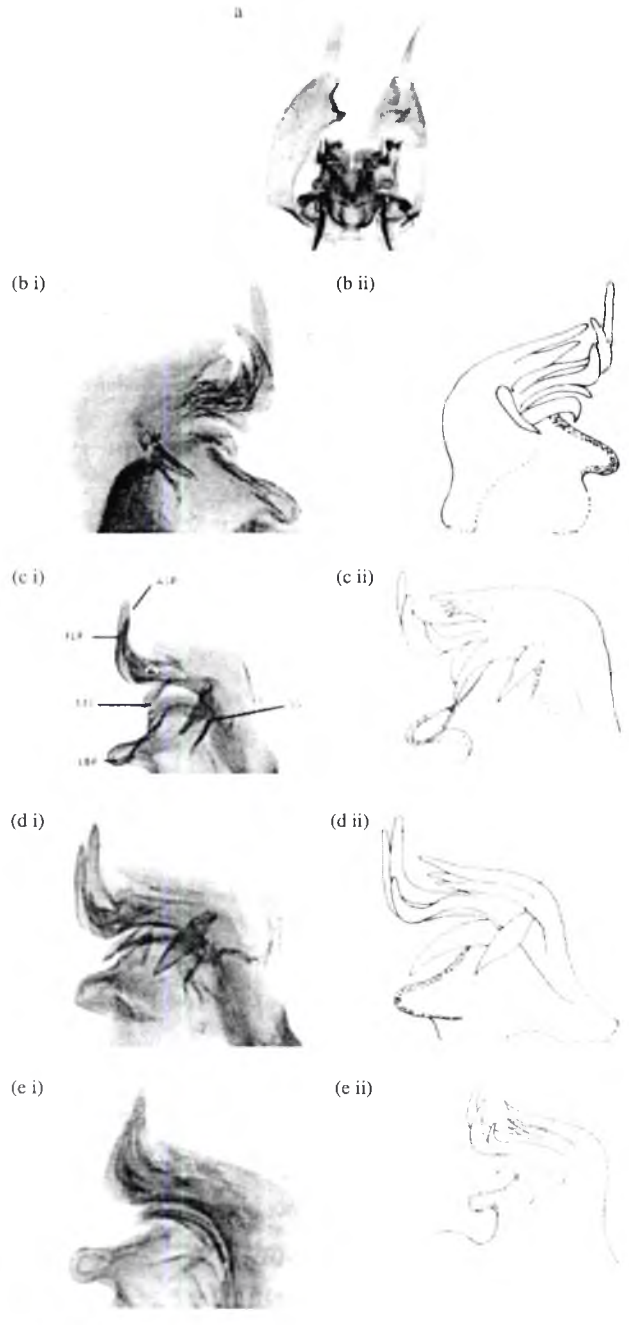


FIGURE 3. Male genitalia of *Culex pseudovishnui*. a, whole view; bi & bii, photograph and drawing of phallosome; ci & cii to ei & eii, photograph and drawing of lateral plate of phallosome of variants I to III.

TABLE 3. Length of various parts of male genitalia of *Culex pseudovishnui*

Part	Length in mm (Mean ± SD) Normal	Variant I	Variant II	Variant III
1st process	0.860 ± 0.070	0.897	0.945	0.842
2nd process	0.614 ± 0.056	0.690	0.857	0.759
3rd process	0.478 ± 0.074	0.581	0.542	0.649
4th process	0.375 ± 0.048	0.412	—	—
Mesal spine	0.541 ± 0.111	0.760	0.760	0.560
Sternal spine	0.550 ± 0.079	0.490	0.490	0.898

Variant I

(Fig. 3 ci, cii): Number of FLP 4, MS broad, longer (0.76 mm) than that in normal. SS slightly shorter (0.49 mm) than the average length of sternal spine of normal mosquitoes (Table 3). LBP narrow, less thickened and well defined.

Variant II

(Fig. 3 di, dii): Number of FLP 3. MS again longer (0.737 mm) than MS of normal males of *Cx. Pseudovishnui* (Table 3). SP long (0.762 mm), broad and pointed. LBP broad, short and thick.

Variant III

(Fig. 3 ei, eii): Number of FLP 3. MS slightly longer (0.56 mm) than normal (Table 3). SS longest of all, with the length of 0.898 mm, broad and pointed. LBP short, broad and well defined.

TAXONOMIC DISCUSSION

Cx. pseudovishnui had been partially or entirely refered to as *Cx. vishnui* Theobald in all previous regional and local studies (Barraud, 1924; Lee, 1944; Bohart and Ingram, 1946; La Casse and Yamaguti, 1950). It was Colless (1957) who for the first time described and recognized *Cx. pseudovishnui*.

During the present investigations it was observed that in *Cx. pseudovishnui*, lot of intraspecific variations exist with respect to the colour of erect scales on vertex, which varies from dull straw to white, pale or dull cream. Colless (1957), Bram (1967) and Sirivanakarn (1975, 1976) reported the presence of pale golden and pale beige to yellowish white scales on the vertex. The length and type of pale band on the proboscis also varies. It is usually narrow but sometimes broad also. According to Colless (1957), the pale band extends up to 1/5th of the length of proboscis. Bram (1967) mentioned the pale band as moderately broad, whereas Reuben (1969) recorded that the width of pale band varies from quarter to one sixth length of proboscis. Tandon

et al. (1995) reported two types of morphological variations in the banding pattern of proboscis — 1/3 length of apex of proboscis dark with remaining length entirely pale or the dark area extending laterally on one side towards the base. According to Colless (1957), the scutal integument is covered with mid to dark brown scales. Bram (1967) observed the variable groupings of brown, pale golden and white scales on the scutum but in the present investigations, the mesonotum has been found to be covered with pale yellow to cream or white scales and golden scales around prescutellar space.

In *Cx. pseudovishnui*, three types of populations are found with respect to variations in male genitalia. These include the number of FLP of phallosome which varies from 3 to 4, and the shape and size of MS, SS and LBP. No previous workers have reported morphological variations in the male genitalia in this species. Colless (1957), while describing the structure of phallosome made a mention of the presence of three or sometimes four pointed teeth on a median process of phallosome. Bram (1967) also noticed the similar pattern of teeth on inner division of phallosome.

ACKNOWLEDGEMENTS

We acknowledge the facilities provided by Centre for Advanced Studies, Department of Zoology, Panjab University, Chandigarh and DAV College, Sector-10, Chandigarh. The financial assistance provided by Department of Science and Technology, Govt. of India in the form of Young Scientist research project is also greatly acknowledged.

REFERENCES

Barraud P. J. (1924) A revision of Culicine mosquitoes of India – Part XI. Some Indian species of *Culex* L. India. Journal of Medical Research, 11: 979–998.

Barraud P. J. (1934) The fauna of British India including Ceylon and Burma. In: *Diptera, Vol. V. Family Culicidae, Tribes Megarhinni and Culicini*, Taylor and Francis, London.

Bohart R. M. and Ingram L. (1946) *Mosquitoes of Okinawa and Islands of Central Pacific*, U.S. Navy Nawmed, Washington, DC, p. 110.

Bram R. A. (1967) Contributions to the mosquitoes fauna of Southeast Asia – II. The genus *Culex* in Thailand (Diptera: Culicidae). Contributions of American Entomological Institute (Ann. Arbor), 2(1): 1–296.

Colless D. H. (1957) Notes on the Culicine mosquitoes of Singapore – II. The *Culex vishnui* group (Diptera: Culicidae), with the description of two new species. Annals of Tropical Medicine and Parasitology, 51: 87–101.

Delfinado M. D. (1966) The Culicine mosquitoes of Philippines, Tribe Culicini (Diptera: Culicidae). Memoirs of the American Entomological Institute. (Ann. Arbor), 7: p. 252.

La Casse W. J. and Yamaguti S. (1950) *Mosquito Fauna of Japan and Korea*, Off Surgeon, 8th U.S. Army, Kyoto, p. 268.

Lee D. J. (1944) An atlas of the mosquito larvae of Australian region. In: *Tribe-Megarhinni and Culicini*, Australian Military Forces, p. 119.

Reuben R. (1969) A redescription of *Culex vishnui* Theobald, with notes on *C. pseudovishnui* Colless and *C. tritaeniorhynchus* Giles, from Southern India. Bulletin of Entomological Research, 58: 643–652.

Reuben R., Tewari S. C., Hiriyan J. and Akiyama J. (1994) Illustrated keys to species of *Culex* (*Culex*) associated with Japanese encephalitis in South-East Asia (Diptera: Culicidae). Mosquito Systematics, 26(2): 75–96.

Sirivanakarn S. (1975) The systematics of *Culex vishnui* complex in Southeast Asia with the diagnosis of three common species (Diptera: Culicidae). Mosquito Systematics, 7(1): 69–86.
Sirivanakarn S. (1976) Medical entomology studies – III. A revision of subgenus *Culex* in the Oriental region (Diptera: Culicidae). Contributions of American Entomological Institute, 12(2): 1–272.
Siverly R. E. and Shroyer D. A. (1974) Illustrated key to the genitalia of male mosquitoes of India. Mosquito Systematics, 6(3): 167–200.
Tandon N., Bhattacharya S., Sen I. and Basak B. (1995) Morphological variations in natural population of *Culex vishnui* complex. Entomon, 20(2): 45–50.

(Received 4 August 2008; accepted 15 August 2009)

ENTOMON 34(3): 137–146 (2010)
Article No. ent.34302

Epicuticular wax and morphological traits associated with resistance to shoot fly, *Atherigona soccata* (Rondani) in sorghum, *Sorghum bicolor*

P. G. Padmaja*, R. Madhusudhana and N. Seetharama

Directorate of Sorghum Research, Rajendranagar, Hyderabad 500 030, Andhra Pradesh, India
Email: padmaja@sorghum.res.in

ABSTRACT: Host plant resistance is a major component for management of the shoot fly, *Atherigona soccata* (Rondani), an important pest of sorghum (*Sorghum bicolor* (L.) Moench). Traits associated with shoot fly resistance were studied to develop an approach for genetic enhancement of resistance. Distinct differences in leaf surface wax structure and trichome morphology were observed between shoot fly resistant and susceptible genotypes. Resistant lines had glossy leaf surface, glaucous wax structure, unicellular pointed trichomes in high density on both leaf surfaces while the susceptible ones were non-glossy, showed ramentaceous crystalline and sculptured wax and bicelluar trichomes. The importance of these traits in breeding shoot fly resistant genotypes is discussed.

KEYWORDS: Shoot fly, epicuticular wax, trichomes, resistance, sorghum

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth major cereal crop after wheat, rice, maize and barley in terms of production and utilization. In India, it is currently grown on 8.51 M Ha with an annual production of 7.63 M T (Directorate of Economics and Statistics, 2006). Among the insect pests that severely damage sorghum crop, shoot fly *Atherigona soccata* (Rondani) is the most destructive pests that limit sorghum production worldwide. It attacks sorghum at seedling stage between 5–25 d after seedling emergence. The losses due to shoot fly have been estimated to be as high as 86% of grain, and 45% of fodder yield (Sukhani and Jotwani, 1980). Although systemic insecticides provide good control of shoot fly, these are not affordable by the majority of the resource-poor farmers. Hence, use of resistant or less susceptible cultivars is desirable. Various factors associated with shoot fly resistance viz., seedling vigour, leaf surface glossiness, trichome density, and leaf surface wetness have been

*Corresponding author

reported (Nwanze *et al.*, 1990; Sharma, 1993; Dhillon *et al.*, 2005) and are being used as selection criteria to improve sorghum for shoot fly resistance. Despite this, the high yielding commercial sorghum cultivars, which occupy around 65% of the sorghum area in India, are highly susceptible to shoot fly attack. This prompted us to explore more traits that confer resistance to shoot fly in sorghum. So far, the role of qualitative differences in trichome morphology on shoot fly resistance has not been reported and limited work has been done on the role of epicuticular wax. In this study, we report the importance of trichome morphology and epicuticular wax structure in relation to shoot fly attack.

MATERIALS AND METHODS

Five sorghum genotypes, 296B (seed parent of 4 commercial sorghum hybrids), M35-1 (a popular post-rainy cultivar), IS 18551 and IS 2312 (resistant checks), and DJ 6514 (susceptible check) were used in the present study. They were evaluated for shoot fly reaction during rainy and post-rainy cropping seasons of 2004 in the shoot fly nursery at the Directorate of Sorghum Research (DSR), Rajendranagar, Hyderabad, India. Planting was done in a randomized block design with three replications, under rainfed conditions. Rows were 0.6 m apart and plots consisted of parallel single rows 4 m long. One week after seedling emergence, thinning was carried out to maintain a spacing of 100 mm between the plants. To attain uniform shoot fly pressure under field conditions, the fishmeal technique (Nwanze *et al.*, 1992) was adopted. No plant protection measures were adopted.

Phenotypic observations were recorded in each replication during both the seasons. Data on shoot fly resistance was recorded on five component traits, viz., leaf surface glossiness, seedling vigour, oviposition, deadhearts and leaf surface trichome density on adaxial and abaxial leaf surfaces.

The intensity of leaf glossiness (GL) was evaluated on 12th day after seedling emergence (DAE) in the morning between 7–8 AM when there is maximum reflection of sunlight from the leaf surface, on 1–5 scale (1, highly glossy = genotypes with pale green, shiny, narrow erect leaves; 5, non-glossy = genotypes with dull green, non-shiny, broad and drooping leaves) (Dhillon *et al.*, 2005). Seedling vigour (SV) was visually evaluated at 14 DAE on 1–5 scale (1, highly vigorous = plants showing maximum height, leaf expansion and robustness; 5, non-vigorous = plants showing poor growth and low leaf expansion) (Dhillon *et al.*, 2005). The number of eggs in five plants was recorded at 21 DAE and expressed as mean number of eggs per plant. The proportion of seedlings with deadhearts was recorded at 28 DAE. To estimate trichome density, samples (about 200 mm^2) of 5th leaf from 12 day old seedlings were collected and processed as per Dhillon *et al.* (2005). Trichomes on both upper and lower leaf surfaces were counted on five randomly selected microscopic fields and the density/mm was calculated. The differences in the epicuticular wax structure and trichome morphology were studied by examining the ultrastructure of the surface of the 5th leaf under scanning electron microscope (SEM). For studying the epicuticular wax structure, the leaf was cut into small pieces and fixed in 3% gluteraldehyde. Post-

TABLE 1. Simple correlation coefficients among component traits of shoot fly resistance

	GL	SV	E21	D28	TDU
SV	0.89				
E21	0.74	0.59			
DH28	0.83	0.74	0.86		
TDU	−0.89	−0.84	−0.65	−0.83	
TDL	−0.87	−0.78	−0.64	−0.85	0.92

GL, leaf glossiness on 1–5 scale (1 = high intensity of glossiness); SV, seedling vigour on 1–5 scale (1 =high vigour); TDU, trichome density on adaxial leaf surface; TDL, trichome density on abaxial leaf surface. Correlation coefficients are significant at $P = 0.0001$.

fixation preservation was done in 2% aqueous osmium tetroxide and then processed for dehydration. Drying was carried out in critical point dryer and the specimens were coated with platinum sputtering (model JEOL JFC-1600) and observed for wax structure under SEM (model Joel JSM-5600). Exposures were made at magnification of 2500x for epicuticular wax structures on the upper leaf surface, and 300x for trichome morphology on upper and lower leaf surfaces.

Analyses of variance except for trichome morphology and wax structure traits were performed on data from each experiment of each environment to test for significant differences between the genotypes to shoot fly attack. Bartlett's test was used to test for homogeneity between environments before combining the data for combined analysis. The mean differences among the genotypes were compared using SED values. Simple correlations between morphological traits and damage parameters were calculated to understand the trait associations in relation to shoot fly incidence.

RESULTS

The genotypes differed significantly for all the traits studied. While IS 18551 and IS 2312 were distinct from other genotypes for leaf glossiness, seedling vigour, trichome morphology, epicuticular wax structure, oviposition and deadhearts, IS 18551 had significantly higher number of trichomes on both upper and lower surfaces as compared to all other genotypes. Leaf glossiness, seedling vigour and trichome density on upper and lower leaf surfaces influenced the ovipositional preference of the shoot fly and deadheart formation (Table 1).

Leaf glossiness

The germplasm lines IS 18551 and IS 2312 were highly glossy (Score 1); M35-1 was medium glossy, while 296B and DJ 6514 (score 4) were non-glossy (Table 2).

TABLE 2. Performance of sorghum genotypes for traits associated with shoot fly resistance during rainy (R), post-rainy (PR) and pooled (P) environments

Trait		Genotypes								
	Environment	IS18551	IS2312	M35-1	DJ6514	296B	SED^g	Mean (Environment)	SED^E	CV (%)
Leaf glossiness (1–5 scale, 1 = high)	R	1.2	1.0	2.7	4.0	4.0	0.25	2.56		12.32
	PR	1.0	1.0	2.7	4.0	3.0	0.21	2.33		11.07
	P	1.0	1.0	2.7	4.0	3.5	0.16	2.45	0.10	11.58
Seedling vigour (1–5 scale, 1 =high)	R	2.0	2.0	2.3	4.0	3.0	0.21	2.66		9.68
	PR	2.0	2.0	2.7	4.0	3.0	0.21	2.73		9.45
	P	2.0	2.0	2.5	4.0	3.0	0.15	2.70	0.09	10.08
Eggs/plant (no.) at 21 DAE	R	1.1	0.9	1.4	2.5	3.0	0.21	1.78		14.21
	PR	0.3	0.4	0.4	1.5	1.5	0.11	0.82		17.67
	P	0.7	0.6	0.9	2.0	2.3	0.12	1.30	0.07	16.36
Proportion of plants with deadhearts at 28 DAE	R	0.42	0.39	0.48	0.82	0.91	5.18	0.60		10.52
	PR	0.17	0.19	0.30	0.78	0.88	7.06	0.46		18.64
	P	0.29	0.29	0.39	0.80	0.90	0.04	0.53	0.02	13.53
Trichome density (no/mm^2)	R-U	112.0	106.0	81.0	26.0	20.0	1.80	69.0		3.20
	R-L	42.0	52.0	39.0	22.0	15.0	1.12	34.0		4.05
	PR-U	95.0	83.0	65.0	18.0	19.0	2.35	56.0		5.14
	PR-L	39.0	51.0	34.0	14.0	14.0	1.93	30.0		7.78
	P-U	103.5	94.5	73.0	22.0	19.5	1.41	62.50	0.89	3.92
	P-L	40.5	051.5	36.5	18.0	14.5	1.15	32.50	0.73	6.22
Wax structure# (1–2 scale)	R	1.0	1.0	1.0	2.0	2.0	–	1.4	–	–
	PR	1.0	1.0	1.0	2.0	2.0	–	1.4	–	–
	P	1.0	1.0	1.0	2.0	2.0	–	1.4	–	–
Trichome morphology$ (1–2 scale)	R	1.0	1.0	1.0	2.0	2.0	–	1.4	–	–
	PR	1.0	1.0	1.0	2.0	2.0	–	1.4	–	–
	P	1.0	1.0	1.0	2.0	2.0	–	1.4	–	–

1 = ramentaceous crystalline and sculptured wax , 2 = glaucous epicuticular wax; $ 1 = unicellular and pointed trichomes, 2= bicellular and blunt trichomes. U , adaxial leaf surface; L, abaxial leaf surface; DAE, days after seedling emergence ; ^{g} = SED for genotypes; ^{E} = SED for environments

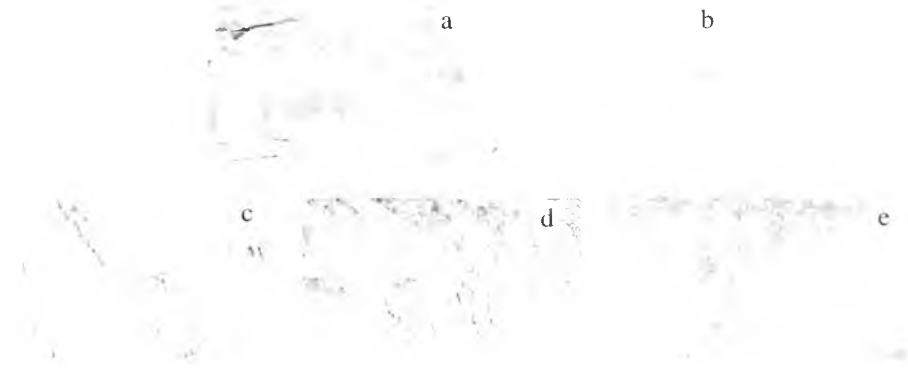


FIGURE 1. Variation in epicuticular wax morphology in sorghum (SEM micrograph). a, b, c, Glaucous epicuticular wax surface in resistant genotypes IS18551, IS2312, and M35-1, respectively. d, e, Ramentaceous epicuticular wax surface in susceptible genotypes 296B and DJ6514, respectively.

Seedling vigour

The germplasm lines IS 18551 and IS 2312 with high seedling vigour showed least damage. In contrast, slow seedling growth due to poor vigour increased the shoot fly damage in DJ 6514 and 296B (Table 2).

Non-preference for oviposition and deadheart formation

Fewer eggs/plant and deadhearts were recorded on the glossy genotypes (IS 18551, IS 2312, M35-1) as compared to non-glossy lines (296B and DJ 6514) during both the seasons.

Epicuticular wax structure

Two distinct morphological differences in the structure of the adaxial epicuticular wax among the five genotypes were observed. A ramentaceous crystalline and sculptured (having scales) epicuticular wax layer was observed on the adaxial surface of non-glossy genotypes 296B and DJ 6514 (Fig. 1) while glaucous (a smooth amorphous wax layer with sparse wax crystals) was observed in glossy genotypes IS 18551, IS 2312 and M35-1.

Trichome morphology and density

Although all five genotypes possessed trichomes on both the leaf surfaces, the trichome shape was different in glossy and non-glossy genotypes. The glossy genotypes (IS 18551, IS 2312 and M35-1) showed unicellular and pointed trichomes, whereas the non-glossy genotypes (296B and DJ 6514) had bicellular and blunt trichomes (Fig. 2 and 3). Trichomes were present on both surfaces of the leaf, but were more abundant on the adaxial surface. The highest number of trichomes was recorded in IS 18551 and the least in 296B, in both the seasons (Table 2).

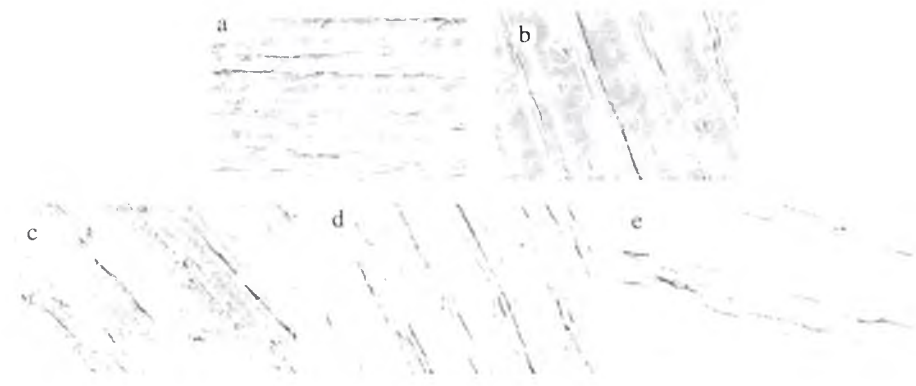


FIGURE 2. Variation in abaxial trichome morphology in sorghum (SEM micrograph). a, b, c, Unicellular and pointed trichomes in resistant genotypes IS18551, IS2312 and M35-1, respectively. d, e, Bicellular and blunt trichomes in susceptible genotypes 296B and DJ6514, respectively.

FIGURE 3. Abaxial trichome morphology (SEM micrograph). A, Unicellular and pointed trichome; b, Bicellular and blunt trichome.

DISCUSSION

Shoot fly incidence was higher in non-glossy than in glossy genotypes in both the seasons. Expression of leaf glossiness in seedlings is an important trait for identifying shoot fly resistance in sorghum (Agrawal and House, 1982). It is clearly manifested during the seedling stage and gradually disappears as the seedling grows (Maiti *et al.*, 1984). The glossy appearance of the leaf is due to change in the structure of epicuticular wax on the leaf surface, with flat plates or sparsely distributed short rods or globules of wax, rather than the dense mat of vertical tubes characteristic of normal wax (non-glossy) (Tarumoto, 2005). Glossiness affects the quality of light reflected from leaves, which in turn influences the orientation of insects towards their host plants (Prokopy *et al.*, 1983). The intensity of glossiness of the leaves during seedling stage is associated with resistance to shoot fly (Sharma *et al.*, 1997; Vijayalakshmi, 1993).

We observed two distinct groups of epicuticular wax structures in glossy and non-glossy genotypes. The glossy genotypes, IS 18551, IS 2312 and M35-1 showed smooth amorphous wax layer with sparse wax crystals while the non-glossy lines 296B and DJ 6514 had a dense meshwork of crystalline wax with small platelets. Insects foraging on plant surfaces must attach to the layer of epicuticular waxes that cover leaf surfaces which enhance or deter oviposition, larval movement and feeding (Eigenbrode, 1996). Glossy crop phenotypes are often less susceptible to insect herbivores than normal phenotypes, and the epicuticular lipids in them are usually reduced in amount and have very different chemical composition and morphology (Eigenbrode and Espelie, 1995). In sorghum also glossy trait has been attributed to the reduction in the number of star-shaped waxes on leaves (Tarumoto, 2005).

The shoot fly adult is unable to attach itself onto the leaf surface of the glossy genotypes for oviposition due to their smooth amorphous epicuticular wax, while in the non-glossy genotypes the crystalline wax may give support for the shoot fly attachment and their oviposition.

A change in surface wax deposition was reported in sorghum by Atkin and Hamilton (1982) and Nwanze *et al.* (1992) similar to that observed in maize (Bianchi and Marchesi, 1960), *Brassica oleracea* (Anstey and Moore, 1954) and Arabidopsis (Jenks *et al.*, 1996). There is a negative correlation between glossiness (smooth amorphous wax crystals) with oviposition and deadhearts (Maiti *et al.*, 1984; Kamatar and Salimath, 2003). The intensity of leaf glossiness at the seedling stage is positively associated with the level of resistance to shoot fly (Sharma *et al.*, 1997). The glossiness expressed by the change in epicuticular wax structure plays an important role in shoot fly resistance, and its modification therefore has great potential for resistance enhancement. The glossiness has been used as a morphological marker in breeding and genetic studies of brassica and maize species, and is related with insect resistance in *Brassica oleracea* (Eigenbrode and Kabalo, 1999) and with resistance to bacterial diseases in *Zea mays* (Marcell and Beattie, 2002).

Leaf surface microroughness is caused by epicuticular wax crystals, cell surface contours, leaf venation, and trichomes (Chester *et al.*, 1995). The presence of trichomes on adaxial surface of the leaf impedes the larval movement towards the growing apex. Therefore, their presence deters oviposition by shoot fly. This can be explained by the present findings that the glossy genotypes (IS 18551 and IS 2312) had more pointed trichomes and less shoot fly damage (% deadheart) while the non-glossy genotypes (296B and DJ 6514) had few bicellular and blunt trichomes and are more susceptible to shoot fly. It is interesting to note that the resistant genotypes (IS 18551, IS 2312 and M35-1) showed only unicellular and pointed trichomes on both the leaf surfaces while the susceptible ones (296B and DJ6514) exhibited bicellular and blunt trichomes. The bicellular trichomes were also reported in grain sorghum and its close relative, *Sorghum halepense* (Johnson grass) (Chester *et al.*, 1995). However, the density of the bicellular trichomes observed in the present study is far less than that was observed in Johnsongrass. Increased trichome density on adaxial and abaxial leaf surfaces is important in reducing the shoot fly incidence since trichome density

was negatively and significantly correlated with oviposition and deadheart formation. Therefore, while improving sorghum for shoot fly resistance, trichome morphology may be used as a morphological marker since unicellular trichomes have been found to be positively associated with shoot fly resistance.

Glossiness and trichome traits together contribute to shoot fly resistance. The presence of trichomes in glossy leaf surface imparts resistance to shoot fly attack. Agrawal and House (1982) and Dhillon *et al.* (2005) also found that the level of resistance was greater when both the glossiness and trichome traits occur together. Omori *et al.* (1983) reported shoot fly egg laying was significantly and negatively associated with trichomes and glossy traits.

Rapid growth of seedlings may retard the first instar larvae from reaching the growing tip. In contrast, slow growth due to poor seedling vigour, low fertility or environmental stress increases shoot fly damage (Taneja and Leuschner, 1985; Patel and Sukhani, 1990). Shoot fly resistant lines have rapid initial plant growth (Mote *et al.*, 1986), greater seedling height and hardness (Singh and Jotwani, 1980) and have longer stems and internodes and short peduncles (Patel and Sukhani, 1990). The relationship between vigour of the plant and its escape from shoot fly attack was also reported by Karanjkar *et al.* (1992). There is a positive correlation between plant height and shoot fly resistance (Khurana and Verma, 1985; Jadhav *et al.*, 1986). Faster growing plants remain in the favourable height (susceptible stage) for a relatively shorter period than the slower growing susceptible plants (Khurana and Verma, 1985). Rapid seedling growth and long, thin seedling leaves make plants less susceptible to shoot fly (Singh, 1998). Genotypes IS 18551, IS 2312 and M35-1 were faster growing and escaped the shoot fly incidence, whereas 296B and DJ 6514 remained in the susceptible stage for relatively longer period and were susceptible to shoot fly. Thus, early seedling vigour traits may be considered as one of the reliable measures of escape from shoot fly infestation. The relationship between vigour of the plant and its escape from shoot fly attack has been reported by Karanjkar *et al.* (1992) and Jadhav *et al.* (1986).

Shoot fly incidence was less in glossy lines and densely trichomed genotypes (IS 18551, IS 2312 and M35-1) and was higher in non-glossy, and bicellular trichomed genotypes (296B and DJ 6514). Based on oviposition behaviour, it was reported by Raina (1982) that colour, texture and width of the sorghum leaf were important factors in selection of the oviposition substrate by female flies. It is concluded from the present study that the glossy leaf surface, with glaucous wax structure and pointed trichomes of high density on both the leaf surfaces and high seedling vigour can be considered as a selection criteria in breeding sorghum for shootfly resistance.

REFERENCES

Agrawal B. L. and House L. R. (1982) Breeding for pest resistance in sorghum. In Sorghum in Eighties. *In Proceedings of the International Symposium on Sorghum*, International Crops Research Institute for the Semi-Arid Tropics, Andhra Pradesh, India, 435–446.

Anstey T. H. and Moore J. F. (1954) Inheritance of glossy foliage and cream petals in green sprouting broccoli. Journal of Heredity, 45: 39–41.

Atkin D. S. J. and Hamilton R. J. (1982) *Surface of Sorghum Bicolor*. Cutler D. F., Alvin K. L. and Price C. E. (Eds). Academic Press, London.

Bianchi A. and Marchesi G. (1960) The surface of the leaf in normal and glossy maize seedlings. Zeitschrift fur Vererbungslehre, 91: 214–219.

Cervantes D. E., Eigenbrode S. D., Ding H. J. and Bosque-Perez N. (2002) Oviposition responses by hessian fly, *Mayetiola destructor*, to wheats varying in surfaces waxes. Journal of Chemical Ecology, 28: 193–210.

Chester G., Mewhorter, Rex N., Paul and Clark Ouzts J. (1995) Bicellular trichomes of Johnsongrass (*Sorghum halepense*) leaves: morphology, histochemistry, and function. Weed Science, 43: 201–208.

Dhillon M. K., Sharma H. C., Singh R. and Naresh J. S. (2005) Mechanisms of resistance to shoot fly, *Atherigona soccata* in sorghum. Euphytica, 144: 301–312.

Eigenbrode S. D. (1996) Plant surface waxes and insect behaviour. In: *Plant Cuticles: an Integrated Functional Approach*, Kerstiens G. (Ed). BIOS Scientific Publishers, Oxford, 201–222.

Eigenbrode S. D. and Espelie K. E. (1995) Effects of plant epicuticular lipids on insect herbivores. Annual Review of Entomology, 40: 171–194.

Eigenbrode S. D. and Kabalo N. N. (1999) Effects of *Brassica oleracea* waxblooms on predation and attachment by *Hippodamia convergens*. Entomologia Experimentalis et Applicata, 91: 125–130.

Jadhav S. S., Mote U. N. and Bapat D. R. (1986) Biophysical plant characters contributing to shoot fly resistance. Sorghum Newsletter, 29: 70.

Jenks M. A., Tuttle H. A., Rashotte A. M. and Feldmann K. A. (1996) Mutants in Arabidopsis altered in epicuticular waxes and leaf morphology. Plant Physiology, 11: 377–385.

Kamatar M. Y. and Salimath P. M. (2003) Morphological traits of sorghum associated with resistance to shoot fly, *Atherigona soccata* Rondani. Indian Journal of Plant Protection, 31: 73–77.

Karanjkar R. R., Chundurwar R. D. and Borikar S. T. (1992) Correlations and path analysis of shoot fly resistance in sorghum. Journal of Maharashtra Agricultural University, 17: 389–391.

Khurana A. D. and Verma A. N. (1985) Some physical plant characters in relation to stem borer and shoot fly resistance in sorghum. Indian Journal of Entomology, 47: 14–19.

Maiti R. K., Prasada Rao K. E., Raju P. S. and House L. R. (1984) The glossy trait in sorghum: its characteristics and significance in crop improvement. Field Crops Research, 9: 279–289.

Marcell L. M. and Beattie G. A. (2002) Effect of leaf surface waxes on leaf colonization by *Pantoea agglomerans* and *Clavibacter michiganensis*. Molecular Plant-Microbe Interactions, 15: 1236–1244.

Mote U. N., Kadma J. R. and Bapat D. R. (1986) Antibiosis mechanism of resistance to sorghum shoot fly. Journal of Maharashtra Agricultural University, 11: 43–46.

Nwanze K. F., Prig R. J., Sree P. S., Butler D. R., Reddy Y. V. R. and Soman P. (1992) Resistance in sorghum to the shoot fly, *Atherigona socata*: epicuticular wax and wetness of the central whorl leaf of young seedlings. Annals of Applied Biology, 120: 373–382.

Nwanze K. F., Reddy Y. V. R. and Soman P. (1990) The role of leaf surface wetness in larval behaviour of the sorghum shoot fly, *Atherigona soccata*. Entomologia Experimentalis et Applicata, 56: 187–195.

Omori T., Agrawal B. L. and House L. R. (1983) Componental analysis of the factors influencing shoot fly resistance in sorghum (*Sorghum bicolor* L. (Moench)) (*Atherigona soccata*). Journal of Agricultural Research Quaterly, 17: 215–218.

Patel G. M. and Sukhani T. R. (1990) Biophysical plant characters associated with shoot fly resistance. Indian Journal of Entomology, 52: 14–17.

Prokopy R. J., Collier R. H. and Finch S. (1983) Leaf color used by cabbage root flies to distinguish among host plants. Science, 221: 190–192.

Raina A. K. (1982) Fecundity and oviposition behaviour of sorghum shoot fly *Atherigona soccata*. Entomologia Experimentalis Applicata, 31: 381–385.

Sharma H. C. (1993) Host-plant resistance to insects in sorghum and its role in integrated pest management. Crop Protection, 12: 11–34.

Sharma H. C., Nwanze K. F. and Subramanian V. (ed) (1997) Mechanisms of resistance to insects and their usefulness in sorghum improvement, International Crop Research Institute for Semi Arid Tropics, Patancheru.

Sharma H. C., Taneja S. L., Leuschner K. and Nwanze K. F. (1992) Techniques to screen sorghums for resistance to insect pests. In: *In Information Bulletin no. 32, vol 48*,, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India.

Singh S. P. (1998) Association of sorghum seedling characters with resistance to shoot fly, *Atherigona soccata* (Rondani). International Sorghum and Millets Newsletter, 39: 115–116.

Singh S. P. and Jotwani (1980) Mechanisms of resistance in sorghum to shoot fly. I. Ovipositional non preference. Indian Journal of Entomology, 42: 240–247.

Statistics D. O. E. A. (2006) Agricultural Statistics at a Glance, Agricultural Statistics Division, Directorate of Agriculture and Cooperation, Ministry of Agriculture, Government of India.

Sukhani T. R. and Jotwani M. G. (1980) Efficacy of mixtures of carbofuran treated and untreated sorghum seed for the control of shoot fly, *Atherigona soccata* (Rondani). Journal of Entomological Research, 4: 186–189.

Taneja S. L. and Leuschner K. (1985) Resistance screening and mechanisms of resistance in sorghum to shoot fly. In: *Proceedings of the International Sorghum Entomology Workshop*, Texas A&M University, College Station, Texas, USA, : International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502324, Andhra Pradesh, India, 115–129.

Tarumoto I. (2005) Glossiness of Leaf Blades in Sorghum (*Sorghum bicolor* L. Moench); Its Visual and Ultrastructural Studies. Japan Agricultural Research Quarterly, 39: 153–160.

Vijayalakshmi K. (1993) Study of the interrelationship of important traits contributing to the resistance of shoot fly in *Sorghum bicolor* (L.) Moench., Andhra Pradesh Agricultural University, Hyderabad.

(Received 04 August 2009; accepted 15 August 2009)

ENTOMON **34(3):** 147–154 (2010)
Article No. ent.34303

Distribution and ecology of root mealybugs associated with black pepper (*Piper nigrum* Linnaeus) in Karnataka and Kerala, India

S. Devasahayam*, K. M. Abdulla Koya, M. Anandaraj, Tresa Thomas and N. Preethi

Indian Institute of Spices Research, Post Box No. 1701, Marikunnu P.O, Calicut 673 012, Kerala, India
Email: devasahayam@spices.res.in

ABSTRACT: Surveys conducted in 297 gardens in 99 locations in Kerala and Karnataka in India showed that five species of mealybugs (*Planococcus* sp., *P. citri*, *P. lilacinus*, *Dysmicoccus brevipes* and *Ferrisia virgata*) infested the roots and basal region of stem (under the soil) of black pepper vines (*Piper nigrum*). Infestation was observed in all the taluks surveyed in Wayanad (Kerala) and Kodagu (Karnataka) districts and also in Udumbanchola, Kozhikode, Taliparamba (Kerala), Alur and Saklespur (Karnataka) taluks. The infestation was positively and significantly correlated with altitude and was observed in all cultivars/varieties, and on vines trailed on all standards (support trees), resulting in defoliation, yellowing and wilting of leaves and mortality of vines. *Phytophthora capsici*, *Meloidogyne incognita* and *Radopholus similis* were associated with root mealybug infested vines. Colonies of root mealybugs were also observed on 18 species of crop/weed plants especially during summer in black pepper gardens infested with the pest. *Anaplolepis* sp., *Crematogaster* sp., *Technomyrmex* sp. and two unidentified species of ants were associated with root mealybug colonies.

KEYWORDS: black pepper, *Piper nigrum*, root mealybug, distribution, damage

INTRODUCTION

Dried mature berries of the perennial climber, *Piper nigrum* Linnaeus (Piperaceae), known as black pepper, is a widely used spice. The crop is grown in about 2,45,970 ha in India, mainly in Kerala and Karnataka (over 98% of total area), with a production of about 69,000 tonnes annually (DASD, 2008). Mealybugs are important pests of the crop, with nine species reported, viz., *Ferrisia virgata* Ckll., *Icerya* sp., *I. aegyptiaca* (Dgl.), *Planococcus* sp., *P. citri* (Risso), *P. minor* (Mask.), *Pseudococcus*

*Corresponding author

sp., *P. longispinus* (Targioni) and *P. orchidicola* Takahashi (Pseudococcidae). All these species except *Planococcus* sp. infest the leaf, shoot and berry (Koya *et al.*, 1996). Increasing reports on damage caused by mealybugs to the roots of black pepper, especially from Wayanad District of Kerala in recent years prompted this investigation on the distribution and ecology of root mealybugs in various major black pepper areas

MATERIALS AND METHODS

The surveys were conducted in 15 taluks in 5 districts (Idukki, Kozhikode, Wayanad, Kannur and Kasaragod) in Kerala and 9 taluks in 4 districts (Dakshina Kannada, Uttara Kannada, Kodagu and Hasan) in Karnataka during 2002–04. These districts account for over 75% of the area under black pepper in the country. The total number of locations and black pepper gardens covered during the survey included 67 and 201 in Kerala and 32 and 96, in Karnataka, respectively (Table 1). The black pepper gardens in various taluks were selected at random based on the information obtained form the Department of Agriculture/Horticulture. From each garden, 15 vines were selected at random and the number of vines with symptoms of damage and incidence of root mealybugs was recorded. Other details of the garden such as altitude, intercrops grown, standards used and cultivars/varieties grown were collected through a standard proforma. The nature of damage caused by root mealybugs and the organisms associated with the pest were studied in the field. Samples of mealybug infested roots were brought to the laboratory and examined for the presence of nematodes and plated for *Phytophthora* sp. and also placed in natural enemy emergence cages to record the predators and parasitoids occurring on them. The ants associated with root mealybug colonies were also recorded in the field. Collections of root mealybugs were also made and preserved in the laboratory for identification. The percentage of vines infested was calculated for each garden/location/taluk. The incidence of root mealybugs in relation to altitude, intercrops grown, standards used and cultivars/varieties grown was also determined.

RESULTS AND DISCUSSION

Distribution of root mealybugs

Root mealybug infestations on black pepper was observed in all the taluks surveyed in Wayanad and Kodagu districts in Kerala and Karnataka and also in Udumbanchola (Idukki District), Kozhikode (Kozhikode District) and Taliparamba (Kannur District) taluks in Kerala and Alur and Saklespur (Hasan District) taluks in Karnataka. The pest infestation was higher in Wayanad (8.0–21.1%) and Kodagu (1.7–15.1%) districts and lower in Idukki (0–3%) and Hasan (0–4.4%) districts; stray infestations of the pest were also observed in Kozhikode and Kannur districts. No infestation was observed in Kasaragod, Dakshina Kannada and Uttara Kannada districts. Among the taluks, the percentage of vines infested by root mealybugs was higher in Vythiri (21.1%) and Virajpet (15.1%) in Kerala and Karnataka, respectively (Table 1). Analysis of the pest infestation in relation to altitude of the location indicated a highly significant and

TABLE 1. Incidence of root mealybugs on black pepper in Kerala and Karnataka

State	District	Taluk	No of locations surveyed	% infested vines (range)	% infested vines (mean)
Kerala	Idukki	Thodupuzha	1	0	0
		Devikulam	2	0	0
		Peerumedu	3	0	0
		Udumbanchola	9	0–6.7	3.0
	Kozhikode	Kozhikode	11	0–2.3	0.4
		Koyilandy	5	0	0
		Vadakara	4	0	0
	Wayanad	Manathavady	3	0–15.5	8.9
		Sultan's Battery	6	0–22.3	8.0
		Vythiri	4	0–33.3	21.1
	Kannur	Thalassery	3	0	0
		Taliparamba	4	0–2.3	0.6
		Kannur	3	0	0
	Kasaragod	Kasaragod	5	0	0
		Hosdrug	4	0	0
Karnataka	Dakshina	Bantwal	3	0	0
	Kannada	Puttur	2	0	0
	Uttara Kananda	Sirsi	5	0	0
	Kodagu	Madikeri	4	0–20.0	5.0
		Somwarpet	4	0–6.7	1.7
		Virajpet	5	4.5–24.5	15.1
	Hasan	Alur	2	0–6.7	3.3
		Belur	3	0	0
		Saklespur	4	0–17.8	4.4

TABLE 2. Incidence of root mealybugs on black pepper in relation to altitude in Kerala and Karnataka

Altitude (m above MSL)	No. of locations	% infestation (range)	% infestation (mean)
0–250	47	0–2.3	0.1
251–500	0	0	0
501–750	16	0–17.8	1.5
751–1000	36	0–33.3	8.9

Correlation: % Infestation vs Altitude ($r = 0.451$).

positive correlation ($r = 0.451$) between pest infestation and altitude. A mean of 0.1% of vines were infested at lower altitudes (0–250 m above MSL) when compared to 8.9% at higher altitudes (751–1000 m above MSL) (Table 2).

Root mealybug infestations were observed on black pepper vines trailed on all standards. The infestation percentage was higher in vines trailed on silver oak (*Grevellia robusta* A. Cunn. ex R. Br.) (18.2%) compared to those on *Erythrina*

TABLE 3. Incidence of root mealybugs on black pepper in relation to standards

District	Standard	No. observed	% Infested
Wayanad, Kerala	*Erythrina* spp.	290	13.1
	Silver oak (*Grevellia robusta*)	115	18.3
	Jack (*Artocarpus* spp.)	82	13.4
	Arecanut (*Areca catechu*)	36	30.6
	Others (including unidentified forest trees)	62	4.8
Kodagu, Karnataka	Silver oak	310	9.6
	Erythrina spp.	90	13.3
	Others (including unidentified forest trees)	185	7.0

TABLE 4. Incidence of root mealybugs on black pepper in relation to cultivars/varieties in Wayanad and Kodagu districts in Kerala and Karnataka

District	Cultivar	No. observed	% infested
Wayanad, Kerala	Panniyur 1	295	13.2
	Karimunda	140	15.7
	Balankotta	46	19.6
	Others (including unidentified cultivars)	100	10.0
Kodagu, Karnataka	Panniyur 1	535	8.2
	Karimunda	24	20.8
	Others (including unidentified cultivars)	26	15.3

spp. (13.1%) and jack (*Artocarpus* spp.) (13.4%), in Wayanad District. In Kodagu District, the infestation percentage was higher (13.3%) in vines trailed on *Erythrina* spp. compared to silver oak (9.6%) and miscellaneous forest trees (7.6%) (Table 3). With regard to cultivars/varieties used, the infestation percentage was higher (19.6%) on Balankotta compared to Karimunda (15.7%) and Panniyur 1 (13.2%), in Wayanad District whereas in Kodagu District it was higher (29.1%) in vines trailed on Karimunda compared to Panniyur 1 (8.2%) (Table 4). With regard to intercrops, 92.1% of locations intercropped with coffee were infested compared to only 7.9% of locations without coffee. At lower altitudes (up to 250 m above MSL) in Kozhikode District where the pest infestation was observed only at two locations out of 11 surveyed, one had coffee as intercrop.

In general, every species is limited in its distribution by biotic and abiotic factors. Among the abiotic factors, climate, especially temperature, rainfall and relative humidity and their interactions between physical and chemical attributes of the host plant, competition among herbivores and natural enemies define the geographic distribution of species (Price, 1984). Climate also determines the physiological tolerances of the insect and host plant and influences insect distribution. The mean maximum and minimum temperatures are lower at higher altitudes and is probably an important factor responsible for the higher incidence of root melaybugs at higher

altitudes. In addition, the availability of other suitable host plants is an important factor.

Five species of mealybugs, namely, *Planococcus* sp., *P. citri* (Risso), *P. lilacinus* (Ckll.), *Dysmicoccus brevipes* (Ckll.) and *Ferrisia virgata* (Ckll.) (Pseudococcidae) were recorded infesting roots and basal portions of stems (under the soil) of black pepper vines. Among them *P. lilacinus* and *D. brevipes* (Ckll.) are being recorded for the first time from black pepper. *P. citri* and *F. virgata* are recorded from the roots/basal regions of stems for the first time. In India, *P. citri* and *P. lilacinus* are known to have a wide host range including many horticultural crops and the hypogeic forms of these species also infest coffee (*Coffea* spp.) in Wayanad and Kodagu districts and are known to cause wilting and mortality especially in younger plants (Sekhar, 1964). *D. brevipes* is a polyphogous species and mainly infests pineapple (*Ananas comosus*) L. (Merr.). In India the hypogeic form has also been recorded on potato (*Solanum tuberosum* L.), groundnut (*Arachis hypogaea* L.), red gram (*Cajanus cajan* (L.) Millsp.), and soybean (*Glycine max*) L. (Merr.) apart from pineapple (Rajagopal *et al.*, 1982; Khan, 1984; Thippaiah and Kumar, 1999). *F. virgata* mainly affects the aerial parts of many horticultural crops in India and has also been recorded to feed on the roots of the weed plant, *Parthenium hysterophorus* L. (Char *et al.*, 1975).

Colonies of root mealybugs were distributed on the main, secondary and tertiary roots and basal region of stems on rooted cuttings in the nursery and also on vines of all age groups in the field. The colonies were observed even up to a depth of two feet below the soil in severely affected vines. The infestation on the basal regions of the stem was seen under the soil and also when they were covered with mulch. Severe infestation resulted in defoliation, yellowing and wilting of leaves and lateral branches and also mortality of vines.

Alternative host plants

In black pepper gardens severely infested with the pest, colonies of root mealybugs were found also on banana (*Musa* sp.) (Musaceae) corm, colocasia (*Colocasia* sp.) (Araceae), turmeric (*Curcuma* sp.) and cardamom (*Elettaria cardamomum* Maton) (Zingiberaceae) rhizome and base of stems of coffee (*Coffea* spp.) (Rubiaceae) and *Erythrina* spp. (Fabaceae) and roots of 11 weed plants (belonging to 10 families including Nephrolepidae) (Table 5). On the weed hosts the insect was generally seen during the post monsoon and summer months. At Wayanad, various intercrops were grown in black pepper gardens among which coconut (*Cocos nucifera* L.), arecanut (*Areca catechu* L.), coffee and banana were the most common and root mealybug infestations were observed in coffee and banana also. In addition, infestation was seen on colocasia, cardamom and turmeric that are grown as intercrops. At Kodagu where coffee was the most common intercrop, followed by *Citrus* sp. and cardamom (*Eletaria cardamomum* Maton) root mealybug infestation was also observed on coffee and cardamom. Six weed species, *Amaranthus gracilis* Desf., *Ludwigia lyssopifolia* Exell., *Solanum nigrum* L., *Mirablis jalapa* L., *Sonchus arvensis* L. and *Spilanthes acmella* L. were reported to harbour *P. lilacinus* at Saklespur, Karnataka (Bhat and

TABLE 5. Alternative host plants of root mealybugs in black pepper gardens

Genus/Species	Family
Nephrolepis sp. Schott	Nephrolepidaceae
Sida acuta Burm.	Malvaceae
Senna tora (L.) Roxb.	Fabaceae
Erythrina sp. L.	Fabaceae
Coffea sp. L.	Rubiaceae
Ageratum conyzoides L.	Asteraceae
Vernonia cinerea (L.) Less.	Asteraceae
Scoparia dulcis L.	Scrophulariaceae
Clerodendron infortunatum L.	Verbenaceae
Achyranthus aspera L.	Amaranthaceae
Phyllanthus niruri L.	Euphorbiaceae
Musa paradisiaca L.	Musaceae
Colocasia sp. Schott	Araceae
Cyperus rotundus L.	Cyperaceae
Heteropogon condortus Beauv. ex Roem. et. Schult	Gramineae
Curcuma longa Roscoe	Zingiberaceae
Elettaria cardamomum Maton	Zingiberaceae
Zingiber officinale Rosc.	Zingiberaceae

Shamanna, 1972). At Hawaii, *D. brevipes* was observed colonizing two species of weeds namely, *Chloris gayana* Kunth. and *Eleusine indica* (L.) Gaertn. (Poaceae) adjacent to pineapple plantations (Pandey and Johnson, 2006). The authors suggest that weed management could play a significant role in reducing pink mealybug movement into pineapple plantings.

Associated organisms

The fungal pathogen, *Phytophthora capsici* and the nematodes, *Meloidogyne incognita* and *Radopholus similis* were commonly associated with root mealybug infested vines. At Wayanad and Kozhikode districts, all the root mealybug infested vines examined ($n = 104$) were also infested with either *P. capsici* and nematodes or both. The infested vines exhibited symptoms such as root rotting, absence of feeder roots, yellowing and wilting of leaves, defoliation and mortality of vines that are characteristically associated with *P. capsici* and nematode infections. At a few locations in Wayanad District the root mealybug colonies (an undetermined species of *Planococcus*) were covered with a fungal colony (unidentified) which formed a soil-encrusted covering lined with mycelia around them. The fungus, *Diacanthodes philippinensis* is reported to be associated with *P. lilacinus* on coffee in India and whenever both occurred together, the plants wilted and died. Infestation by the mealybug alone did not cause the death of coffee plants (Sekhar, 1964; Chacko and Sreedharan, 1981). In Africa, the coffee root mealybug earlier identified as *P. citri* and associated with the fungus *D. novoguineesis* (Hennings) Fidalgo has been later described as a new

species, *P. fungicola* (Watson and Cox, 1990). According to Fidalgo (1962) the fungus is a symbiont providing protected cavities on the root surface in which the mealybugs live in return for the sugars in the honeydew excreted by the insects and in the sap that escapes from the insects' feeding punctures in the roots.

Five species of ants including *Anaplolepis* sp., *Crematogaster* sp., *Technomyrmex* sp. and two unidentified species were associated with root mealybug colonies and in many cases it was easier to identify infested vines based on the activity of ants. Many species of ants are associated with root mealybugs across the world. Le Pelley (1968) has given a detailed account of the relationship of various species of ants with mealybugs infesting coffee. In India, nine species of ants are reported to be associated with mealybugs on coffee in Kodagu and Wayanad districts (Venkataramaiah and Rehman, 1989).

Among the natural enemies, only larvae of *Spalgis* sp. (Spaligidae) were observed to predate on root mealybug colonies especially those at the base of the stems. *Spalgis* sp. is a well-known predator of mealybugs in many parts of the world and in India *S. epius* Westwood has been identified as a potential predator of the mealybug complex of *P. citri*, *P. lilacinus* and *F. virgata*, occurring on shoots of coffee. Though numerous natural enemies have been recoded on mealybug species occurring on the aerial parts of the plant, the hypogeic habit of the root mealybugs probably render them difficult for predation and parasitisation by natural enemies.

ACKNOWLEDGEMENTS

We are thankful to Indian Council of Agricultural Research, New Delhi, for financial assistance and Director, Indian Institute of Spices Research, Calicut, for facilities. We are also thankful to Dr. G. W. Watson, California Department of Agriculture, Sacramento, USA, and Dr. P. A. Rahiman, Regional Coffee Research Station, Chundale, Kerala, for identification of root mealybugs, Dr. K. V. Saji, Senior Scientist, for identification of weed hosts, Mr. K. K. Sasidharan, Technical Assistant, for assistance during surveys and Mr. K. Jayarajan, Technical Officer, Indian Institute of Spices Research, Calicut, for analysis of data.

REFERENCES

Bhat P. K. and Shamanna H. V. (1972) Some new collateral hosts of *Planococcus lilacinus* from South India. J. Coffee Res., 2: 27.

Chacko M. J. and Sreedharan K. (1981) Control of *Planococcus lilacinus* and *Diacanthodes* sp. associated with coffee roots. J. Coffee Res., 11: 76–80.

Char M. B. S., Nagendran C. R. and Ganesh D. (1975) Mealy bugs on the roots of Parthenium weed. Curr. Sci., 44: 207.

(DASD) Directorate of Arecanut and Spices Development (2008) *Area and Production Statistics of Arecanut and Spices*, Directorate of Arecanut and Spices Development, Calicut, p. 74.

Fidalgo O. (1962) Type studies and revision of the genus *Diacanthodes* Sing. Rickia, 1: 145–180.

Khan J. D. K. (1984) India-pineapple mealy-bug on potato. FAO Plant Prot. Bull., 32(3): 113.

Koya K. M. A., Devasahayam S., Selvakumaran S. and Kallil S. (1996) Distribution and damage caused by scale insects and mealy bugs associated with black pepper (*Piper nigrum* Linnaeus) in India. J. Entomol. Res., 20: 129–136.

Le Pelley R. H. (1968) *Pests of Coffee*, Longmans, London, p. 590.

Pandey R. R. and Johnson M. W. (2006) Weeds adjacent to Hawaiian pineapple plantings harboring pink pineapple mealybugs. Environ. Entomol., 35: 68–74.

Price P. W. (1984) The concept of the ecosystem. In: *Ecological Entomology*, Huffaker C. B. and Rabb R. L. (Eds), John Wiley and Sons, New York, 19–52.

Rajagopal D., Siddaramegowda T. K. and Rajagopal B. K. (1982) Incidence of pineapple mealybug *Dysmicoccus brevic eps* (Cockerell)on rhizobium nodules of redgram and groundnut. J. Soil Biol. Ecol., 2: 97–98.

Sekhar P. S. (1964) Pests of coffee. In: *Entomology in India*, Entomological Society of India, New Delhi, p. 529.

Thippaiah N. G. and Kumar (1999) *Dysmicoccus* sp. (Pseudococcidae: Homoptera): a pest of soyabean in Karnataka. Insect Environ., 5(2): 70.

Venkataramaiah G. H. and Rehman P. A. (1989) Ants associated with the mealybugs of coffee. Indian Coffee, 43: 13–14.

Watson G. W. and Cox J. M. (1990) Identification of the African coffee root mealybug, with descriptions two new species of *Planococcus* (Homoptera: Pseudococcidae). Bull. Entomol. Res., 80: 99–105.

(Received 04 August 2009; accepted 15 August 2009)

ENTOMON **34(3):** 155–166 (2010)
Article No. ent.34304

Colydiidae of Andaman and Nicobar Islands, India, with three new species (Coleoptera: Heteromera)

T. K. Pal

Zoological Survey of India, M – Block, New Alipore, Kolkata 700 053, India
Email: tkpal51@rediffmail.com

ABSTRACT: Eight species of Colydiidae *viz.*, *Bitoma siccana* (Pascoe), *Lasconotus lushaicus* Pal, *Colobicus parilis* Pascoe, *Cerchanotus orientalis* (Slipinski), *Endeitoma rugicollis* sp. nov., *Neotrichus longicollis* sp. nov., *Synchita brunneus* sp. nov. and *Pycnomerus nitidicollis* (Reitter) are recorded and the new species described, from Andaman & Nicobar Is.

KEYWORDS: Coleoptera, Colydiidae, new species, Andaman & Nicobar Is

INTRODUCTION

The Colydiidae are a moderately large family of the superfamily Heteromera (=Tenebrionoidea) of the suborder Polyphaga. The family is yet to be sufficiently worked out in both the specific and supraspecific levels. Over the years, the family Colydiidae have been used as a repository of various genera, both Clavicornia and Heteromera, which possessed features like 4-segmented tarsi and clubbed antennae (Lawrence, 1980). The family Colydiidae was erected by Erichson (1842) and in the Lacordaire's scheme of classification in 1854 it included several genera, now distributed in various clavicorn and heteromeroid families. This broad perception of the familial assemblage was followed by Reitter (1911) dealing with the fauna Germany and by Hetschko (1930) for the preparation of world catalogue of Coleoptera. The constitution of the family has been changed considerably since the publication of Hetschko's Catalogue in 1930. Crowson (1955) made notable moderation in the constitution of the Colydiidae. He transferred Cerylonini, Murmidiinae and Euxestinae to the Clavicorn family Cerylonidae and retained the remaining colydiids in the section Heteromera under two subfamilies, *viz.*, Colydiinae and Bothriderinae. Subsequently, there was a consideration by some coleopterists dealing with higher taxa (especially J.F. Lawrence) that Colydiidae as delineated by Crowson (1955) to be an assemblage of both clavicorns and heteromerans. The recent treatment by Pal and Lawrence (1986) has accepted the genera close to *Bothrideres* (Bothriderinae *sensu* Crowson) as a separate family, Bothrideridae. The remainders of the heteromeroid genera of the world were listed and

arranged under 10 tribes of Colydiidae by Ivie and Slipinski (1990). This treatment is followed in the present account.

The colydiids are small to moderately large beetles that occur in dead wood, under bark, leaf litter, etc. in both adult and larval stages. Several species are predators on wood inhabiting larvae of insects. Since Grouvelle (1908), Pal (1984, 2003, 2007)) and Pal and Slipinski (1984) described five species of Colydiidae from India. The family is hitherto unrecorded from the insular parts of India. Recently, during field work in Andaman & Nicobar Islands colydiid beetles were collected from woodland and vegetation, an inventory of which, including description of three new species, is given here.

SYSTEMATICS

Family COLYDIIDAE

Tribe SYNCHITINI

*Genus **Bitoma** Herbst*

1793. *Bitoma* Herbst, *Natursystem der Insekten*: Käfer **5**: 25 [Type species: *Tritoma crenata* Fabricius].
1807. *Ditoma* Illiger, *Magazin für Isektenkunde* , **6**: 320.
1857. *Euditoma* Gistel, *Vacuna*, **2**: 26.
1863. *Coniophaea* Pasco, *J. Ent.*, **2**: 90.
1873. *Synchytodes* Crotch, *Checklist Col. North America*: 45.
1882. *Synchitodes*: Retter, *Best-Tab. eur. Col.* **6**: 130.

Distribution : North, Central and South America; Europe; Africa; Efypt; Syria; India; Sri Lanka; Myanmar; Japan; Philippines; Indonesia; Australia; New Zealand; Pacific Islands.

***Bitoma siccana** (Pascoe)*

1863. *Xuthia siccana* Pascoe, *J. Ent.*, **2**: 128.
1863. *Xuthia rufina* Pascoe, *J. Ent.*, **2**: 128.
1863. *Xuthia maura* Pascoe, *J. Ent.*, **2**: 129.
1867. *Bitoma lyctiformis* Wollaston, *Col. Hesperidum*: 63.
1885. *Xuthia parallela* Sharp, *J. Linn. Soc. Lond.*, **19**: 70.
1892. *Bitoma elongata* Grouvelle, *Annls. Soc. Ent. Fr.*, **59**: 296.
1898. *Bitoma rufipes* Kolbe, *Deutsch. Ost.-Afr.*, **4** Käfer : 111.
1908. *Xuthia siccana* : Grouvelle, *Annls. Soc. Ent. Fr.*, **77**: 399.
1930. *Bitoma siccana* : Hetschko, *Col. Cat.*, **107**:19.
1980. *Bitoma siccana* : Dajoz, *Faune de Madagascar* : 28.
1985. *Bitoma siccana* : Slipinski, *Pol. Pismo Ent.*, **55**: 485.

New record: Material : 523 ex. INDIA: Andaman Is., South Andaman, Chatham, Port Blair, 168 ex., 5.x.2001, T.K. Pal & Party, *ex.* under bark; Chouldari, 6 ex., 28.ix.2003, T.K. Pal & Party, *ex.* under bark; Sipighat, 55 ex., 7.x.2001, T.K. Pal & Party, *ex.* under bark; Lorazig, 10 km. O-Nilambur, 55 ex., 22.ii.2000, T.K. Pal & Party, *ex.* under bark; Middle Andaman, Yerata, 12 km. O-Bakultala, 7 ex., 18.ii.2000, T.K. Pal & Party, *ex.* under bark; Pooltala, 6 ex., 20.ii.2000, T.K. Pal & Party, *ex.* under bark; Nimbutala, 18 km. O-Bakultala, 5 ex., 20.x.2001, T.K. Pal & Party, *ex.* under bark; North Andaman, Danapur, nr. Mayabunder, 25 ex., 22.x.2001, T.K. Pal & Party, *ex.* under bark; Kalara 11 km. N-O Kalighat, 115 ex., 24.x.2001, T.K. Pal & Party, *ex.* under bark; Little Andaman, Vivekanandapur, 28 km. O-Hut Bay, 10 ex., 2001, T.K. Pal & Party, *ex.* under bark; Hut Bay, 68 ex., 9.x.2001, T.K. Pal & Party, *ex.* under bark; Great Nicobar, Campbell Bay, 3 ex., 7.x.2003, T.K. Pal & Party, *ex.* under bark.

Distribution : India: Sikkim, West Bengal, Mizoram, Tamil Nadu, Andaman & Nicobar Is.; Bhutan; Nepal; Myanmar; Sri Lanka; Japan; Indonesia; Seychelles Is.; Mascarene Is.; New Guinea; New Caledonia; Madagascar; Reunion; Mauritius; Guinea Bissau; South Africa; Saudi Arabia.

Genus ***Lasconotus*** *Erichson*

1845. *Lasconotus* Erichson, *Natur. Ins. Deutschl., Col.*, (1) **3**: p. 258 nota. [Type species: *Lasconotus complex* Le Conte].
1867. *Lado* Wankowicz, *Ann. Soc. Ent. Fr.* (4) **7**: 249.
1863. *Illeustus* Pascoe, *J. Ent.* **2**: 33.
1863. *Ithris* Pascoe, *J.Ent.* **2**: 134.
1871. *Othismopteryx* J. Sahlberg, *Not. Sallsk. Faun. Flor. Fenn. Forh.* **11**: 441.
1935. *Lasconotus* : Hinton, *Rev. Ent.* **5**: 204.
1935. *Chrysopogonius* Hinton, *Rev. Ent.* **5**: 207.
1997. *Lasconotus*: Slipinki & Lawrence, *Ann. Zool.* **47**: 392.

Distribution : North and Central America; India; Nepal; Australia; Papua.

Lasconotus lushaicus *Pal*

2007. *Lasconotus lushaicus* Pal, *Zool. Surv. India, State Fauna Ser.* **14** *Fauna of Mizoram*: 310.

New record: Material : 1 ex., India: Andaman Is., Middle Andaman, Yerata, 12 km. O-Bakultala, 18.ii.2000, T.K. Pal & party, *ex.* under bark.

Distribution : India: Mizoram, Andaman Is.

Genus ***Colobicus*** *Latreille*

1807. *Colobicus* Latreille, *Genera Crustaceorum et insectorum*, **2**: 9. [Type-species: *Colobicus marginatus* Latreille].

Distribution : Russia; Middle Europe; Continental Africa; Madagascar; Reunion; Mauritius; India; Myanmar; Sri Lanka; Indonesia; Malaysia; Philippines; Hawaii Is.

Colobicus *parilis Pascoe*

1860. *Colobicus parilis* Pascoe, *J. Ent.*, **1**: 202.
1863. *Colobicus conformis* Pascoe, *J. Ent.*, **2**: 124.
1908. *Colobicus parilis*: Grouvelle, *Annls. Soc. Ent. Fr.*, **77**: 406.
1909. *Colobicus parilis*: Arrow, *Ann. Mag. Nat. Hist.*, (8) **4**: 193.

New record: Material : 12 ex. INDIA: Andaman Is., South Andaman, Chatham, Port Blair, 9 ex., 13.ii.2000, T.K. Pal & party, *ex.* under bark; Lorazig, 10 km. O-Nilambur, 1 ex., 22.ii.2000, T.K. Pal & party, *ex.* under bark; Middle Andaman, Yerata, 12 km. O-Bakultala, 2 ex., 18.ii.2000, T.K. Pal & party, *ex.* under bark.

Distribution : India: Sikkim, Kerala (Mahe), Andaman Is.; Myanmar; Philippines; Indonesia (Moluccas); Hawaii Is.

Genus ***Cerchanotus*** *Erichson*

1845. *Cerchanotus* Erichson, *Naturg. Ins. Deutschl. Col.* **3**: 257 [Type species: *Syntarsus asperulus* Fairmaire, by subsequent designation].
1869. *Syntarsus* Fairmaire, *Annls. Soc. ent. Fr.* **9** (4): 205.
1990. *Asprecodes* Nakane, *Kita-kyushu no Konchu*, **37** (2): 66.

Distribution : Madagascar; South China; Japan; India; Nepal; Bhutan; Sri Lanka; Malaysia; Indonesia; Philippines; Australia; New Guinea.

Cerchanotus orientalis *(Slipinski)*

1985. *Syntarsus orientalis* Slipinski, *Annls. Zoologici*, **39**: 183.
1908. *Cebia rugosa* (nec. Pascoe): Grouvelle, *Annls. Soc. ent. Fr.* **77**: 412.
1975. *Cebia rugosa* (nec. Pascoe): Dajoz, *Ent. Basel.* **1**: 297.
2003. *Cerchanotus orientalis*: Pal, *Zool. Surv. India, State Fauna Ser.* **9**, *Fauna of Sikkim*: 169.

New record: Material : 1 ex. India: Andaman Is., South Andaman, Chatham, Port Blair, 13.ii.2000, T.K. Pal & party, *ex.* under bark.

Distribution : India: Sikkim, Andaman Is.; Bhutan; Nepal; Sri Lanka; Indonesia (Sumatra); Australia.

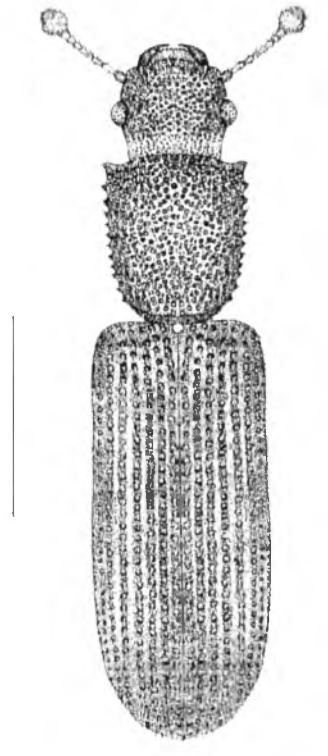


FIGURE 1. *Endeitoma rugicollis* sp. nov., Dorsal view (Scale = 1.0 mm).

Genus ***Endeitoma*** *Sharp*

1894. *Endeitoma* Sharp, *Biologia-Centralia Americana*, Coloptera, **2**(1): 450 [Type-species: *Endeitoma mexicana* Sharp].
1899. *Keklasmenus* Sharp, *Entomologist's Mon. Mag.*, **10**(2): 9.
1937. *Pabula* Carter & Zeck, *Proc. Linn. Soc. N.S.W.*, **62**:193.
1980. *Mahetrichus* Dajoz, *Faune de Madagascar*, **54**: 37.

Distribution : All major biogeographic regions except Palaearctic, and New Zealand. This is the first record of the genus from India.

Endeitoma rugicollis sp. nov.

General appearance (Fig. 1) rather narrowly elongate, moderately depressed, reddish-brown to dark brown, head and pronotum with rugose punctuations, dorsum setose and rather dull.

Exposed part of head moderately transverse, mouth parts partly exposed, anterior margin of clypeus slightly arcuate, shallow longitudinal impressions on frons over

antennal bases, eyes about one-third as long as exposed part of head and moderately projecting, temple about half as long as eye, neck constriction not distinct but post-ocular neck-line apparent; antenna slightly longer than exposad part of head, scape oblong and hidden under frons, pedicel narrower than scape and somewhat globes, segment 3 narrower and longer than pedicel, segments 4–8 short, subequal, about as broad as long or slightly transverse, segment 9 slightly wider than preceding segment, basal segment of club (segment 10) broad and transverse, apical segment (segment 11) shorter, narrower and more pubescent ; disc of frons and vertex with distinctly raised tubercles (rugose punctures), tubercles separated by less than their diameter and each bearing an erect squamiferous seta, clypeal apex non-tuberculate.

Prothrax elongate (1.1:1.0), sides almost straight and slightly narrowed from apex to base, front angles produced and hind angles not very well marked, pronotum with moderately impressed preapical and prebasal margins, lateral margins not explanate and distinctly dentate, pronotal disc set with rugose tubercles, size of tubercles almost similar to those on vertex of head, tubercles separated by much less than their diameter and bear squamiferous setae.

Scutellum about as broad as long, round apically and impunctate.

Elytra more than twice as long as broad (2.3:1.0), convex, rather parallel-sided and slightly broader towards posterior third, apex rounded, sides not explante; punctures of striae coarse, separated longitudinally by about one diameter, interstices about as wide as diameter of punctures, intervals between punctures on striae feebly tuberculate and each bearing squamiferous seta; puncturation on ventral side much finer, no squamiferous seta.

Measurements of holotype : Total length 3.50 mm, width of head across eyes 0.64 mm, length of antenna 0.60 mm, length and width of prothorax 0.82 mm and 0.72 mm,length and width of elytra 2.13 mm and 0.89 mm.

Holotype (sex indet.) : India: Andaman Is., South Andaman, Chatham, Port Blair.13.ii 2000, T. K. Pal, *ex.* under bark; ***Paratype***, 1 ex., data same as holotype; ***Paratype***, 1 ex., South Andaman, Lorazig, 10 km. O-Nilambur, 22.ii.2000, T. K. Pal, *ex.* under bark; ***Paratypes***, 5 ex., Middle Andaman, Nimbulata, 18 km. O-Bakultala, 20.10.2000 T. K. Pal, *ex.* under bark (Zoological survey of India).

Etymology : The species-name refers to rugose tuberosities on the dorsum of prothorax.

Remarks : This species shows some resemblances with *Endeitoma parallelocollis* (Grouvelle) from Seychalles but can be differentiated by its distinctly elongate prothorax (vs. about as broad as long in *parallelocollis*) and dentitions on sides more pronounced.

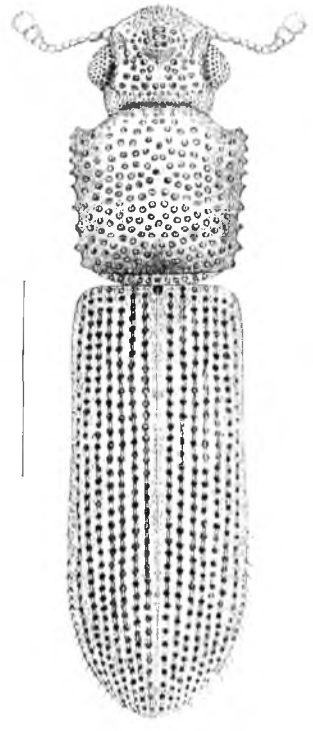


FIGURE 2. *Neotrichus longicollis* sp. nov., Dorsal view (Scale = 1.0 mm).

Genus ***Neotrichu s*** *Sharp*

1886. *Neotrichus* Sharp, *J. Linn. Soc. Lond.*, **19**:61 [Type-species: *Neotrichus hispidus* sharp].

Distribution : South America, Africa, Seychelles, Japan, Sri Lanka, India, Australia.

***Neotrichus longicollis* sp. nov.**

General appearance (Fig. 2) rather narrowly elongate moderately depressed, dark brown, head and pronoterm with rugose punctuations, dorsum with scant setae, not very dull.

Exposed part of head moderately transverse, mouthparts partly exposed by not seen from above, anterior margin of clypeus slightly arcuate, shallow longitudinal impressions on frons above antennal bases, eyes about one-third as long as head and moderately projecting, temple short and slightly extended beneath eye, no post-ocular neck constriction; antenna slightly longer then exposed part of head, scape oblong and partly hidden under frons, pedicel narrower than scape and somewhat globose,

segment 3 narrower than pedicel and slightly elongate, segments 4–9 short, subequal about as broad as long or slightly transverse, basal segment of club (segment 10) broad and transverse, apical segment (segment 11) about as broad as long and not quite narrower than preceding segment; disc of frons and vertex with distinctly raised and flat-topped round tubercles (rugose puncture), tubercles separated by 0.5–1.0 diameter, clypeal apex more finely tuberculate.

Prothrax elongate (1.1:1.0), sides almost straight and slightly narrowed from apex to base, front angles produced and hind angles not very well marked, pronoteum with moderately impressed prebasal margins lateral margin, lateral margins not explanate and distinctly dentate, pronotal disc set with rugose tubercles and slightly larger in size than those on vertex of head, tubercles separated by 0.5–1.0 diameter.

Scutellum about as broad as long, round apically and punctuate.

Elytra more than twice as long as broad (2.5:1.0), convex, rather parallel-sided and slightly broader towards posterior third, apex rounded, sides not explanate; punctures of striae coarse, separated longitudinally by about one diameter, interstices about as wide as diameter of punctures, intervals between punctures on striae feebly tuberculate, squamiferous setae on tubercles near lateral borders; puncturation on ventral side much finer.

Measurements of holotype : Total length 3.64 mm, width of head across eyes 0.51 mm, length of antenna 0.61 mm, length and width of prothorax 0.91 mm and 0.80 mm, length and width of elytra 2.15 mm and 0.84 mm.

Holotype (sex indet.) : India: Nicobar Is., Great Nicobar, 35 km.O-Campbell Bay, 8.xii.1978, B.N. Nandi & party, *ex.* decaying log (Zoological survey of India).

Etymology : The species-name refers to the elongate prothorax of the species.

Remarks : This species shows some resemblances with the lone Indian species, *Neotrichus afoevicollis* Pal from Sikkim but can be distinguished by its longer body, frons above antennal bases more elevated, elongated prothorax not explanate on sides (vs. about as broad as long with explanate sides in *afovecollis*), pronotum devoid of distinctly impressed preapical margin; and more elongate elytra.

Genus ***Synchita*** *Hellwig*

1792. *Synchita* Hellwig (in) Schneider, *Neuest. Mag. Ent.*, **1** (4): 401 [Type-species: *Synchita juglandis* Hellwig].
1824. *Cicones* Curtis, *British Entomology*, **4**: 149.
1863. *Bupala* Pascoe, *J. Ent.*, **2**:125.
1922. *Pseudosynchita* Pic, *Rev. Linn.*, **38** (408): 21.
1939. *Pseudocicones* Fursov, *Bull. Soc. Nat. Mosc.*, Sec. Biologique (n.s.) **48** (1):88.

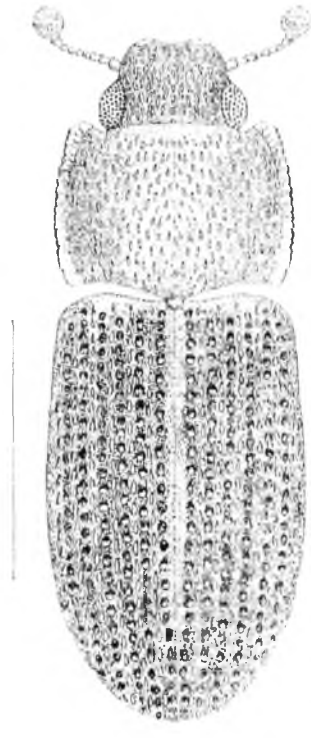


FIGURE 3. *Synchita brunneus* sp. nov., Dorsal view (Scale = 1.0 mm).

Distribution : North, Central & South America, Europe, Continental Africa, Madagascar, Seychelles, Japan, Sri Lanka, India. This is the first record of the genus from India.

Synchita brunneus *sp. nov.*

General appearance (Fig, 3) elongate, subdepressed, dorsally dull and covered with squamiform setae.

Head transverse, anterior margin of clypeus slightly notched, no depression or elevation on frons; eyes more than half as long as head, moderately projecting; temple not visible from above, neck hidden under pronotum; antenna slightly longer than head, scape oblong and hidden under frons, pedicel narrower than scape and oblongate, segment 3 narrower and slightly shorter than pedicel, segments 4–8 short, subequal, about as broad as long or slightly transverse, segment 9 slightly wider than preceding segment, club abrupt, somewhat balloon-like, slightly elongate with a transverse impression near middle, apical part of the club more densely setose; disc of frons and vertex with moderately coarse punctures, punctures separated by about their

diameter, covered with moderately dense and semierect squamiferous setae, clypeal part more finely punctuate.

Prothorax transverse (1.0:1.4), sides slightly arcuate, slightly narrowed towards apex and base; front angles produced, blunt and somewhat acute, hind angles slightly obtuse; pronotum with moderately impressed prebasal margin, lateral margins slightly explanate and serrate; pronotal disc set with moderately coarse punctures, punctures separated by less than their diameter, covered with moderately dense and semierect squamiferous setae.

Scutellum slightly transverse, round apically and punctuate.

Elytra less than twice as long as broad (1.6:1.0), convex, sides subparallel or feebly arched, slightly broader towards posterior third, apex rounded, sides slightly explanate; punctures of striae coarse, separated longitudinally by about one diameter, interstices about as wide as diameter of punctures, intervals between punctures on striae feebly tuberculate and bearing squamiferous setae in linear rows; puncturation on ventral side much finer, no squamiferous seta.

Measurements of holotype : Total length 2.60 mm, width of head across eyes 0.40 mm, length of antenna 0.46 mm, length and width of prothorex 0.65 mm and 0.91 mm, length and width of elytra 1.66 mm and 1.03 mm.

Holotype (sex indet) : India: Andaman Is., South Andaman, Chatham, Port Blair, 13.ii.2000, T. K. Pal, *ex.* under bark; ***Paratypes***, 5 ex. data same as holotype (Zoological Survey of India).

Etymology : The species-name refers to the deep brown colour of the beetle.

Remarks : This species shows some resemblances with *Synchita compactus* (Grouvelle) from Seychelles but can be differentiated by its antennal club marginally elongate (vs. distinctly elongate in *compactus*) and more elongate elytra (1.6x as long as broad vs. 1.3x as long as broad in *compactus*).

TRIBE PYCNOMERINI

Genus ***Pycnomerus*** *Erichson*

1842. *Pycnomerus* Erichson, *Archiv für Naturgeschichte*, **8** (1): 214 [Type species: *Ips terebrans* Olivier].
1860. *Penthelispa* Pascoe, *J. Ent.*, **1**: 111.
1861. *Endectus* LeConte, *Classif. Col. N. Amer.*, **1**: 91.
1899. *Pycnomeroplesius* Ganglbauer, *Die. Käfer von Mitteleuropa*, **3**: 885.

Distribution : North, Central and South America; West Indies; Continental Africa; Madagascar; India; Sri Lanka; Indonesia; Australia; Tasmania; New Zealand.

Pycnomerus nitidicollis *(Reitter)*

1877. *Penthelispa nitidicollis* Reitter, *Stettin. Ent. Ztg.* **38**: 305.
1908. *Pycnomerus nitidicollis*: Grouvelle, *Annls. Soc. Ent. Fr.* **77**: 428.

New record: Material : 43 ex. INDIA: Andaman Is., South Andaman, Lorazig, 10 km. O- Nilambur, 1 ex., 22.ii.2000, T.K. Pal & party, *ex.* under bark; Middle Andaman, Betapur, 35 km. O-Bakultala, 1 ex., 19.x.2000, T.K. Pal & party, *ex.* fungusy log; Great Nicobar Is., Campbell Bay, 1 ex., 3.xi.1978, B. Nandi & party, *ex.* Dhup log; 24 km. S-O Campbell Bay, 1 ex., 2.xii. 1978, B. Nandi & party, *ex.* decaying Mango log; Campbell Bay, 8 ex., 7.x.2003, T.K. Pal & party, *ex.* under bark; Sital Pahar, 15 km. W-O Campbell Bay, 30 ex., 10.x.2003, T.K. Pal & party, *ex.* Badam log; Shastri Nagar, 14 km. O- Campbell Bay, 1 ex., 4.x.2003, T.K. Pal & party, *ex.* under bark;

Distribution : India: Sikkim, Tamil Nadu, Andaman & Nicobar Is.; Sri Lanka.

ACKNOWLEDGEMENTS

I am indebted to the Director, Zoological Survey of India, for providing necessary facilities for the work.

REFERENCES

Crowson R. A. (1955) *The Natural Classification of the Families of Coleoptera*, Nathaniel Lloyd, London, p. 187.

Erichson W. F. (1842) Beitrag zur Insecten-Fauna von Vandiemensland, mit besonderer Berücksichtigung der geographischen Verbreitung der Insekten. Achiv für Naturgeschichte, 8(1): 83–287.pls. IV–V

Grouvelle A. (1908) Coléoptères de la region indienne. Rhysodidae, Trogositidae, Nitidulidae, Colydiidae, Cucujidae. Annales de la Societe Entomologique de France, 77: 315–495.pls. 6–9

Hetschko A. (1930) Colydiidae. In: Junk & Schenkling eds. Coleopterorum Catalogus; pars, 107: 1–124.

Ivie M. A. and Slipinski S. A. (1990) Catalog of the genera of World Colydiidae (Coleoptera). Annales Zoologici, 43 (Suppl. 1): 32.

Lacordaire J. T. (1854) Histoire naturelle des Insectes. Genera des Coleopteres ou esposé méthodique de tous les genres Proposés jusqu'ci dans cet ordre d'insectes. Paris, 2: 1–548.

Lawrence J. F. (1980) A new genus of Indo-Australian gempylodini with notes on the constitution of the Colydiidae (Coleoptera). Journal of the Australian Entomological Society, 19: 293–310.

Pal T. K. (1984) Two new species of *Pseudendestes* Lawrence (Coleoptera: Colydiidae) from India. Bulletin of the Zoological Survey of India, 6: 31–35.

Pal T. K. (2003) Insecta: Coleoptera: Colydiidae. Zoological Survey of India; State Fauna Series 6: Fauna of Sikkim (Part-3), 73–85.

Pal T. K. (2007) Insecta: Coleoptera: Colydiidae. Zoological Survey of India; State Fauna Series 14: Fauna of Mizoram, 307–312.

Pal T. K. and Lawrence J. F. (1986) A new genus and subfamily of mycophagous Bothrideridae (Coleoptera: Cucujoidea) from the Indo-Australian region with notes on related families. Journal of the Australian Entomological Society, 25: 185–210.

Pal T. K. and Slipinski S. A. (1984) Notes on *Nematidium* Erichson (Coleoptera: Colydiidae) with description of new species. Polskie Pismo Entomologiczne, 53: 531–543.
Reitter E. (1911) *Fauna Germanica*. Die Käfer des Deutschen Reiches. Nach der analytischen Methode bearbeitet. Stuttgart, 3: 1–436,pls. 81–128

(Received 25 March 2009; accepted 15 August 2009)

ENTOMON 34(3): 167–174 (2010)
Article No. ent.34305

Description of a new species of the genus *Rhachisphora* Quaintance & Baker (Hemiptera: Aleyrodidae) with a key to Indian species

R. Pushpa and R. Sundararaj*

Wood Biodegradation Division, Institute of Wood Science and Technology, 18th Cross Malleswaram, Bangalore 560 003, India
Email: rsundararaj@icfre.org

ABSTRACT: The whitefly genus *Rhachisphora* Quaintance & Baker from India is reviewed and a new species *Rhachisphora combiformis* sp. nov. breeding on *Persea macrantha* is described and illustrated. A key to the Indian species of the genus is given.

KEYWORDS: Aleyrodidae, new species, *Rhachisphora combiformis*

INTRODUCTION

Quaintance and Baker (1917) erected the whitefly genus *Rhachisphora* as a subgenus under *Dialeurodes* Cockerell. Takahashi (1952) elevated *Rhachisphora* to generic level. In India, this genus is represented by seven species *viz.*, *R. elongatus* Regu & David, *R. indica* Sundararaj & David, *R. ixorae* Sundararaj & David, *R. kallarensis* Jesudasan & David, *R. pechipparaiensis* David & David, *R. rutherfordi* (Quaintance & Baker) and *R. trilobitoides* (Quaintance & Baker). In this paper the genus *Rhachisphora* from India is reviewed and a new species from south India is described. In addition a workable key to the Indian species of the genus is given.

Genus *Rhachisphora* Quaintance and Baker, 1917

Dialeurodes (*Rhachisphora*) Quaintance and Baker, 1917. *Proc. U. S. Natl. Mus.*, 51: 430.

Type species: *Dialeurodes* (*Rhachisphora*) *trilobitoides* Quaintance and Baker, 1917. *Proc. U. S. Natl. Mus.*, 51: 430 - 431; by original designation.
Rhachisphora Quaintance & Baker; as full genus, Takahashi, 1952. *Mushi*, 24: 22.

*Corresponding author

Greeniella (David, 1993). *FIPPAT Entomology Series*, 3: 22. Type species: *Rhachisphora capitatis*, by monotypy (A junior homonym of *Greeniella* (Cockerell, 1897): *American Naturalist*, 31: 703 (Synonymised by (Martin and Mound, 2007)).

Diagnosis

Puparia pale or brownish, occasionally black; margin irregular or broadly crenulate, indented as a pore at each caudal and thoracic tracheal openings in margin. Submargin often with about 12 pairs of tiny lanceolate setae. Dorsal disc with a prominent submedian rhachis with or without lateral arms. Submargin not separated from dorsal disc by a continuous fold but a pair of longitudinal subdorsal furrows often present cephalothoracically. Vasiform orifice subcircular or subcordate; operculum filling the orifice; lingula concealed. Caudal furrow usually pronounced. Cuticle often very ornately sculptured.

KEY TO THE PUPARIUM OF INDIAN SPECIES OF *RHACHISPHORA*

1. Puparium not pale; submarginal setae/spines present; rhachis without comb-like structures 2
– Puparium pale; submarginal setae/spines absent; rhachis with comb-like structures ..... *combiformis* sp. nov.
2. Puparium tortoise-shaped or much elongated; transverse moulting suture terminating at margin or submargin laterad of metathoracic or I/II abdominal segment suture; lanceolate and capitate setae present on dorsum 3
– Puparium shape different; transverse moulting suture curved cephalad terminating at cephalic margin; lanceolate and capitate setae absent on dorsum 5
3. Puparium tortoise-shaped; margin with 8–10 crenulations in 0.1 mm; laterally radiating subdorsal ridges present 4
– Puparium much elongated; margin with 16–17 crenulations in 0.1 mm; laterally radiating subdorsal ridges absent ..... *elongatus* Regu & David
4. Puparium oval; submargin fringed with at least 10 pairs lanceolate setae and 40 pairs of capitate setae; dorsum with 23 pairs of capitate setae; first abdominal setae present ..... *pechipparaiensis* David & David
– Puparium elliptical; submargin with 12 pairs of lanceolate setae; dorsum with numerous capitate setae (about 300 pairs); first abdominal setae absent ..... *rutherfordi* (Quaintance & Baker)
5. Puparium heart-shaped, broadest across thoracic region 6
– Puparium elliptical, broadest across abdominal segments I–II ..... *ixorae* Sundararaj & David
6. Puparium 1.06–1.42 mm long and 0.98–1.30 mm wide, not tapering in anterior and posterior end; submargin without oval-shaped pores 7

– Puparium 1.163–1.623 mm long and 0.877–1.255 mm wide, tapering in anterior and posterior end; submargin with oval-shaped pores ..... *kallarensis* Jesudasan & David

7. Margin crenulate; ridge from metathoracic segment long with polygonal markings; first abdominal setae present ..... *trilobitoides* (Quaintance & Baker)

– Margin smooth; ridge from metathoracic segment short without polygonal markings; first abdominal setae wanting ..... *indica* Sundararaj & David

1. *Rhachisphora combiformis* sp. nov. (Figures 1–4)

Puparium

White, without secretion of wax; broadly elliptical, broadest at third abdominal segment; not dimorphic, 0.94–1.48 mm long, 0.72–1.18 mm wide; found in groups on the under surface of leaves. Margin smooth, no teeth evident; thoracic and caudal tracheal openings at margin in the form of a small pore without internal teeth; anterior and posterior marginal setae each 10 μm long.

Dorsum

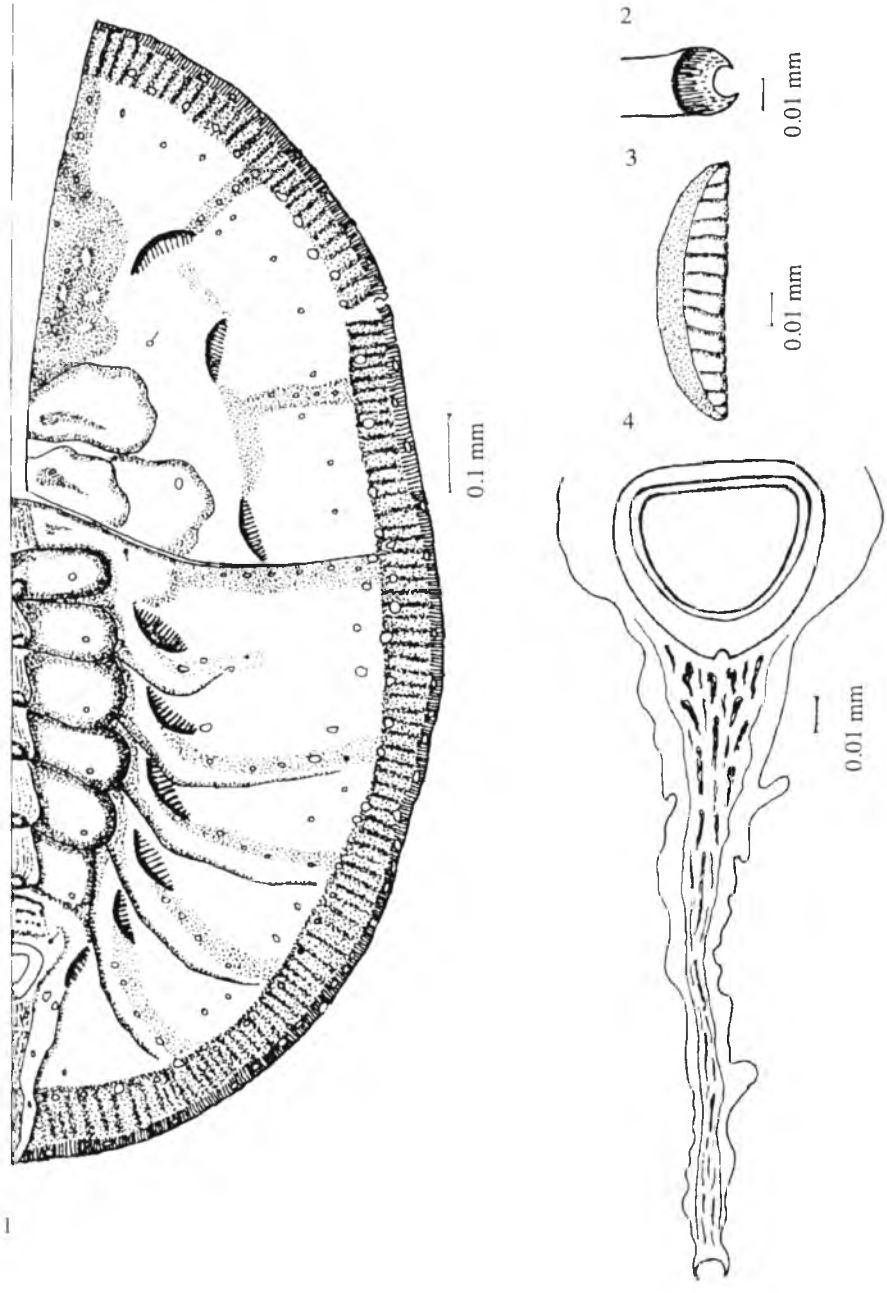
Submedian rhachis distinct with its lateral arms extending up to subdorsum, the radiating arms with 9 pairs of teeth-like structures giving the appearance of combs — 3 pairs on cephalothorax and 6 pairs on abdomen. Margin striated with uneven row of round markings, submargin defined by narrow glandular furrows mesad from marginal striations, inner submargin with uneven row of mushroom-shaped structures about 7.5 μm diameter, subdorsum with a similar uneven row, additionally a few arranged in rows above the arms of the rhachis. Longitudinal moulting suture reaching margin, bounded by a shallow keeled extension of rhachis; the broad caudal furrow similarly situated on a shallowly elevated extension of the rhachis which is having faint wavy markings; transverse moulting suture reaching submargin. Median of abdominal segments II–VII with triangular tubercle-like structures. Faint depressions present on prothorax. Thoracic and caudal tracheal furrows distinct. Caudal furrow 190–196 μm long and 48–60 μm wide at its broadest end with irregular stout striations.

Chaetotaxy

Cephalic and first abdominal setae lanceolate, each 4–6 μm long, eighth abdominal setae pointed, 4μm long and caudal setae not discernible. Dorsum with sparsely scattered numerous minute lanceolate setae, a submedian row on abdominal segments II–VII distinct.

Vasiform orifice

Subcircular, 60–64 μm long, 70–74 μm wide; operculum similarly shaped 40–46 μm long, 46–56 μm wide, filling orifice and obscuring lingula.



FIGURES 1–4. *Rhachisphora combiformis* Pushpa and Sundararaj sp. nov.: 1. Puparium; 2. Thoracic tracheal pore; 3. Comb-like structure; 4. Vasiform Orifice.

Venter

Paired ventral abdominal setae 8 μm long, 26 μm apart; thoracic tracheal folds indicated by a pair of lines running mesad from pores while caudal tracheal folds faintly indicated.

Material examined

Holotype

Puparium, India: Karnataka: Nagarahole Rajiv Gandhi National Park, on *Persea macrantha*, 14.iii.06, Coll. R. Pushpa, deposited in Forest Entomology Division, Forest Research Institute, Dehradun, India.

Paratypes

5 puparia, data as for holotype, one paratype each deposited in the collection of Division of Entomology, Indian Agricultural Research Institute, New Delhi, India and Zoological Survey of India, Kolkata, India and the remaining in the collection of Institute of Wood Science & Technology, Bangalore, India.

Distribution

India: Karnataka.

Etymology

Named to reflect the comb-like structures in the subdorsum.

Remarks

This species resembles *R. queenslandica* Martin by the presence of row of mushroom-shaped structures on dorsum, but differs from all other known species in having pale puparium and presence of comb-like structures and by the absence of submarginal setae/spines.

2. *Rhachisphora elongatus* Regu & David

Rhachisphora elongatus (Regu and David, 1990). *Entomon*, 15(3&4): 277–279.

Material examined

India: Tamil Nadu: Kunnathoor, holotype puparium of *Rhachisphora elongatus* Regu & David, on *Mimusops elengi*, 24.i.1989, Coll. K. Regu.

Host: *Mimusops elengi* (Regu and David, 1990).
Distribution: India: Tamil Nadu: Kunnathoor (Regu and David, 1990).

3. *RHACHISPHORA INDICA* SUNDARARAJ & DAVID

Rhachisphora indica (Sundararaj and David, 1991). *Entomon*, 16(4): 311–315.

Material examined

India: Tamil Nadu: Munchirai, holotype puparium on unidentified plant, 6.viii.1987, Coll. R. Sundararaj.
Host: Unidentified plant (Sundararaj and David, 1991).
Distribution: India: Tamil Nadu: Munchirai (Sundararaj and David, 1991).

4. *RHACHISPHORA IXORAE* SUNDARARAJ & DAVID

Rhachisphora ixorae (Sundararaj and David, 1991). *Entomon*, 16: 311–315.
Material examined: India: Tamil Nadu: Kayarambedu, holotype puparium on *Ixora* sp, 6.iii.1971, Coll. B.V. David; Karnataka: Bangalore, 9 puparia, on *Murraya koenigii*, 04.iv.07, Coll. R. Sundararaj; Kolar, 13 puparia, on *Ixora pavetta* 04.iv.07, Coll. R. Sundararaj.
Hosts: *Ixora* sp. (Sundararaj and David, 1991); *Ixora pavetta*, *Murraya koenigii* (new host records).
Distribution: India: Tamil Nadu: Kayarambedu (Sundararaj and David, 1991); Karnataka (new distribution record).

5. *RHACHISPHORA KALLARENSIS* JESUDASAN & DAVID

Rhachisphora kallarensis (Jesudasan and David, 1991). *Oriental Ins.*, 25: 324–325.
Material examined: India: Tamil Nadu: Kallar, holotype puparium on unidentified tree, 20.vi.1985, Coll. R.W. Alexander Jesudasan.
Host: Unidentified tree (Jesudasan and David, 1991).
Distribution: India: Tamil Nadu: Kallar (Jesudasan and David, 1991).

6. *RHACHISPHORA PECHIPPARAIENSIS* DAVID & DAVID

Rhachisphora pechipparaiensis (David and David, 2007). *Oriental Ins.*, 41: 404.
Material examined: India: Tamil Nadu: Pechipparai, 1 puparium on *Icnocarpus frutescens*, 13.iii.1993, Coll. P.M.M. David.
Host: *Icnocarpus frutescens* (David and David, 2007).
Distribution: India: Tamil Nadu (David and David, 2007).

7. *RHACHISPHORA RUTHERFORDI* (QUAINTANCE & BAKER)

Dialeurodes (Rhachisphora) (Sic) *rutherfordi* (Quaintance and Baker, 1917). 432–433. Syntypes on *Loranthus* sp., Sri Lanka, Peradeniya, vi. 1913 (A. Rutherford) USNM).
Rhachisphora rutherfordi (Quaintance & Baker), (Mound and Halsey, 1978). 187; (David and Regu, 1991). *J. Insect Sci.*, 4(1): 69–70.

Material examined: India: Tamil Nadu: Kunnathoor, 3 puparia on *Loranthus elasticus*, 24.1.1989, Coll. K. Regu.

Host: *Loranthus elasticus* (David and Regu, 1991).

Distribution: India: Tamil Nadu: Kunnathoor (David and Regu, 1991).

8. *RHACHISPHORA TRILOBITOIDES* (QUAINTANCE & BAKER)

Dialeurodes (Rhachisphora) trilobitoides (Quaintance and Baker, 1917). *Proc. U.S. Natl. Mus.*, 51: 433.

Dialeurodes trilobitoides: (Singh, 1931). *Mem. Dep. Agric. India*, 12(1): 28.

Rhachisphora trilobitoides (Takahashi, 1952). *Mushi*, 24: 22; (David and Subramaniam, 1976). *Rec. Zool. Surv. India*, 70: 211; (Sundararaj and David, 1991). *Entomon*, 16(4): 315.

Rhachisphora madhucae (Jesudasan and David, 1991). *Oriental Ins.*, 25: 325. (Synonymised by Sundararaj & Dubey, 2006).

Material examined: India: Tamil Nadu: Madras, holotype puparium, on *Madhuca longifolia*, 9.i.1985, Coll. R.W.A. Jesudasan; Point Calimere, 10 puparia on *Memecylon umbellatum*, 20.iii.07, Coll. R. Pushpa ; Point Calimere, 11 puparia on *Manilkara hexandra*, 20.iii.07, Coll. R. Pushpa; Point Calimere, 12 puparia on *Mimusops elengi*, 20.iii.07, Coll. R. Pushpa.

Hosts: *Cordia myxa, Eugenia jambos* (Singh, 1931); *Mimusops hexandra* (Rao, 1958); *Randia (Xeromphis) malabarica* (David and Subramaniam, 1976); *Mimusops elengi, Strychnos nux-vomica* (Sundararaj and David, 1991); *Madhuca longifolia* (Jesudasan and David, 1991); *Manilkara hexandra, Memecylon umbellatum* (new host records).

Distribution: India: Bihar (Pusa) (Singh, 1931); Andhra Pradesh (Rao, 1958); Tamil Nadu (David and Subramaniam, 1976; Sundararaj and David, 1991).

ACKNOWLEDGEMENTS

We are grateful to the Director and Group Coordinator (Research) IWST, Bangalore for the facilities provided. Thanks are due to Prof. B.V. David, President, Sun Agro Bio-tech Research Centre, Porur, Chennai for loaning the types, going through the manuscripts and valuable comments.

REFERENCES

Cockerell T. D. A. (1897) The Coccidae of Ceylon by E. E. Green.. American Naturalist, 31: 701–704.

David B. V. (1993) The whitefly of Sri Lanka (Homoptera: Aleyrodidae). *FIPPAT*. Entomology Series, 3: 1–32.

David P. M. M. and David B. V. (2007) Descriptions of new species of whiteflies (Hemiptera: Aleyrodidae) from south India. Oriental Insects, 41: 391–426.

David B. V. and Regu K. (1991) A new record and redescription of *Rhachisphora rutherfordi* (Quaintance & Baker) (Homoptera: Aleyrodidae) from India. Journal of Insect Science, 4(1): 69–70.

David B. V. and Subramaniam T. R. (1976) Studies on some Indian Aleyrodidae. Records of the Zoological Survey of India, 70: 133–233.

Jesudasan R. W. A. and David B. V. (1991) Taxonomic studies on Indian Aleyrodidae (Insecta: Homoptera). Oriental Insects, 25: 231–434.

Martin J. H. and Mound L. A. (2007) An annotated check list of the world's whiteflies (Insecta: Hemiptera: Aleyrodidae). Zootaxa, 1492: 1–84.

Mound L.A and Halsey S. H. (1978) *A Systematic Catalogue of the Aleyrodidae (Homoptera) with Host Plant and Natural Enemy Data*, British Museum (Natural History) and John Wiley and Sons, Chichester, p. 340.

Quaintance A. L. and Baker A. C. (1917) A contribution to our knowledge of the whiteflies of the subfamily Aleyrodinae (Aleyrodidae). Proceedings of the United States National Museum, 51: 335–445.

Rao A. S. (1958) Notes on Indian Aleurodidae (Whiteflies) with special reference to Hyderabad. In Proceedings 10th International Congress of Entomology, 1: 331–326.

Regu K. and David B. V. (1990) *Rhachisphora elongatus* sp. nov. (Aleyrodidae Homoptera) — a new species of whitefly from India. Entomon, 15: 277–279.

Singh K. (1931) A contribution towards our knowledge of the Aleyrodidae (whiteflies) of India. Memoirs of the Department of Agriculture in India (Entomological Series), 12: 1–98.

Sundararaj R. and David B. V. (1991) On the whiteflies of the genus *Rhachisphora* Quaintance & Baker (Aleyrodidae: Homoptera) from India. Entomon, 16(4): 311–315.

Takahashi R. (1952) Some Malayan species of Aleyrodidae (Homoptera). Mushi, 24: 21–27.

(Received 23 March 2009; accepted 15 August 2009)

ENTOMON 34(3): 175–180 (2010)
Article No. ent.34306

Predatory mites of the genus *Agistemus* (Acari: Stigmaeidae) from medicinal plants of West Bengal, India, with description of a new species

Indranil Roy, Salil K. Gupta and Goutam K. Saha*

Entomology and Wildlife Biology Research Laboratory, Department of Zoology, University of Calcutta, 35 Ballygunge Circular Road, Kolkata 700 019, West Bengal, India
Email: indranilzoology@gmail.com
Email: gkszoo@rediffmail.com

ABSTRACT: A new species of the genus *Agistemus* (Acari: Stigmaeidae) is recorded from West Bengal, India and described. New records of three species, viz., *Agistemus edulis* Gupta, *A. flescheneri* Summers and *A. terminalis* (Quayle) are also reported. A key is provided to separate *Agistemus* mites infesting medicinal plants in West Bengal.

KEYWORDS: Stigmaeidae, *Agistemus*, new species, new records, medicinal plants

INTRODUCTION

A systematic survey was conducted in different parts of West Bengal to explore the phytophagus and predatory mites infesting medicinal plants. From this survey several new species of mites were described and new records on some host plants or habitat reported earlier (Lahiri *et al.*, 2005; Roy *et al.*, 2006, 2008a,b). This paper deals with the description of a new species of the genus *Agistemus* (Family: Stigmaeidae). This predatory mite is of great significance in controlling phytophagous mites and also small soft bodied insects and their eggs (Nelson *et al.*, 1973; Childers and Enns, 1975; Muma, 1975; Childers, 1994). Other five species of *Agistemus* infesting medicinal plants of West Bengal are also reported in this paper including three new records on respective habitats. Holotypes and paratypes are kept in the Entomology and Wildlife Biology Research Laboratory, University of Calcutta, which in due course will be deposited in the National collection of Zoological Survey of India, Kolkata. The senior author did the entire collection. Measurements of the new species described in this paper are in microns.

*Corresponding author

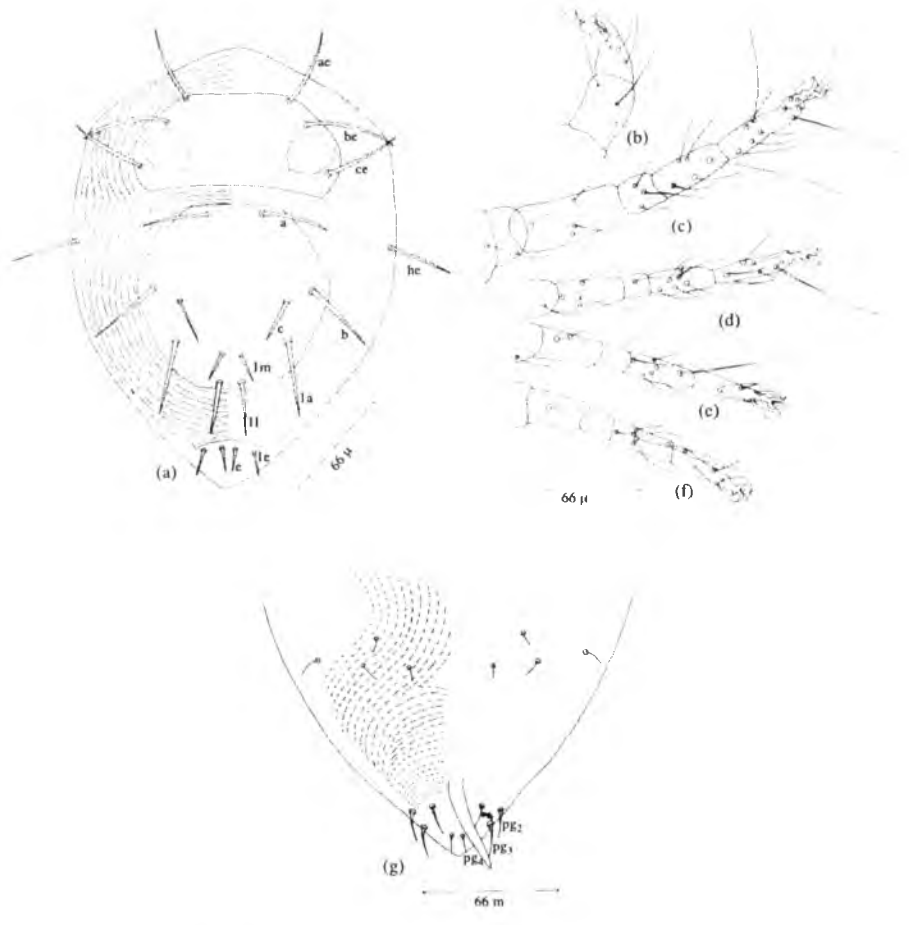


FIGURE 1. Male of *Agistemus albae* sp. nov. a, Dorsal view; b, Dorsal aspect of terminal segments of palp; c, Leg I; d, Leg II; e, Leg III; f, Leg IV; g, Venter of male opisthosoma with aedeagus.

FAMILY: STIGMAEIDAE OUDEMANS

1931. Stigmaeidae Oudemans, Ent. Ber., 7(158): 252.
Genus: *Agistemus* Summers
1927. *Zetzellia* Oudemans, *Ent. Ber. Amst.*, 7(158): 263 (in part)

1. *AGISTEMUS ALBAE* SP. NOV. (FIG. 1A–G)

Diagnosis:

Male: Body from posterior tip upto base of chelicera 264 long and 165 wide. Palp 99 long, palp claw well developed and 20 long. Chelicera 76 long. Dorsal propodosomal

TABLE 1. Leg chaetotaxy of male *Agistemus alba* sp. nov.

Leg	Coxa	Trochanter	Femur	Genu	Tibia	Tarsus
I	1D	1L	1D, 1L, 2V	1D, 2L	1D, 4L	4L, 3D, 2V, 1S
II	–	1D	2D, 2V	1D	4D, 1V, 1L	5D, 2L, 1S
III	–	1D	1D, 1V	–	2D, 2V, 2L.	1D, 1L, 2V
IV		1V			3D, 2V, 1L	2D, 3L

D, Dorsal; V, Ventral; L, Lateral; S, Solenidium

plate not reticulate, 83 long and 116 wide with 3 pairs of setae. Postocular body large, inconspicuously outlined 29 long and 26 wide; Median plate 89 long and 99 wide with 6 pairs of setae. Dorsal setae thick gently serrate. Measurement of setae, distance between seatae: ae-33, be-39, ce-36, ae-ae-33, be-be-53, ce-ce-106, ae/ae-ae-1, be/be-be-0.74, ce/ce-ce-0.34, a-33, b-33, c-30, a-a-33, b-b-99, c-c-66, a/a-a-1, b/b-b-0.33, c/c-c-0.44, he-30, la-33, lm-17, li-26, e-13, le-13. Integument transversely striated between propodosomal and median plates and area lateral to median plate longitudinally striated. Anogenital setae 4 pairs. Pg3 the longest. Aedegus 40 long. Measurement of legs: Leg I 231, Leg II 165, Leg III-175 and Leg IV 165; all the legs terminate in a pair of claws. Tarsus I possesses a pair of long setae. Leg chaetotaxy as figured and the number of setae on different leg segments shown in Table 1.

Female: Not known

Material examined

Holotype

Male, India: West Bengal, Darjeeling, 5th Mile Conservation Site, Siliguri, ex *Morus alba* Linn., dated: 23.11.2006. coll. Indranil Roy.

Paratype

1 male, same data as for holotype.

Etymology

The species name is after the host plant.

Remarks

This new species is close to *Agistemus terminalis* (Quayle) (Gupta, 2002), but differs from that in the following points: (i) lm and li equal in length in *A. terminalis*, but in the new species li longer than lm. (ii) In the new species a/a-a is almost double than that of corresponding ratio in *A. terminalis*. (iii) The postocular body touches almost be and ce in the new species, but not in *A. terminalis*.

2. *AGISTEMUS EDULIS* GUPTA

1991. *Agistemus edulis* Gupta, *Rec. Zool. Surv. India*, **88**: 218.

Collection records: 4 females, India: West Bengal, 24 Parganas (S), Narendrapur, Medicinal Plant Garden-Narendrapur Ramakrishna Mission Ashrama, ex *Aegle marmelos* Corr. Ex Roxb. dated: 23.10.2005.

Habitat (Medicinal plants): *Mangifera indica* (Lahiri *et al.*, 2004), *A. marmelos* (New Report).

Distribution: India: West Bengal (Gupta, 2002).

3. *AGISTEMUS FLESCHENERI* SUMMERS

1960. *Agistemus flescheneri* Summers, *Proc. Ent. Soc. Wash.*, **62**: 237-240.

Collection records: 2 females, India: West Bengal, Midnapore (West), Chandrakona Rd,Parimal Kanan, ex *Desmodium gangeticum* DC., dated: 21.01.2007.

Habitat (Medicinal plants): *Stephania japonica*, *Urena sinuata* (Gupta, 2005); *Desmodium gangeticum* (New Report).

Distribution: India: West Bengal (Gupta, 2002); Elsewhere: Mexico (Gonzalez-Rodriguez, 1965).

4. *AGISTEMUS LOBATA* ROY *ET AL.*

2006. *Agistemus lobata* Roy *et al*, *Entomon*, 31(4): 307-313.

Collection records: 3 females, India: West Bengal, 24 Parganas (S), Narendrapur, Medicinal Plant Garden-Narendrapur Ramakrishna Mission Ashrama, ex *Urena lobata* Linn. dated: 13.06.2005.

Habitat (Medicinal plants): *U. lobata* (Roy *et al.*, 2006).

Distribution: India: West Bengal (Roy *et al.*, 2006).

5. *AGISTEMUS SIMPLEX* GONZALEZ-RODRIGUEZ

1965. *Agistemus simplex* Gonzalez-Rodriguez, *Univ. Calif. Pub. Ent.*, 33–34.

Collection records: 2 females, India: West Bengal, Darjeeling, Salugara, ex *Zingiber* sp., dated: 22.11.2006.

Habitat (Medicinal plants): *Azadirachta indica*, (Ghosh and Gupta, 2003); *Zingiber* sp. (Roy *et al.*, 2008b).

Distribution: India: West Bengal (Gupta, 2002); Elsewhere: Mexico (Gonzalez-Rodriguez, 1965).

6. *AGISTEMUS TERMINALIS* (QUAYLE)

Collection records: 3 females.: West Bengal, Jalpaiguri, Butabari, ex *Dioscorea* sp., ex *Dioscorea* sp ., dated: 08.03.2008.

Habitat (Medicinal plants): Papaya, citrus (Gupta, 2002); *Dioscorea* sp. (New report).

Distribution: India: Mizoram, Sikkim, Tripura,West Bengal; Elsewhere: U.S.A., Mexico, Guatemala, Japan (Gupta, 2002).

7. *AGISTEMUS UNGUIPARVUS* GONZALEZ-RODRIGUEZ

1965. *Agistemus unguiparvus* Gonzalez-Rodriguez, *Univ. Calif. Pub. Ent.*, 41-43.

Collection records: 3 females, India: West Bengal, Darjeeling, Sukna, ex *Aristolochia indica* L., dated: 24.11.2006.

Habitat (Medicinal plants): Citrus, cotton (Gupta, 2002); *A. indica* (Roy *et al.*, 2008b).

Distribution: India: Uttar Pradesh, Tripura (Gupta, 2002), West Bengal (Roy *et al.*, 2008b); Elsewhere: Mozambique (Gupta, 2002).

Following Gupta (2002), a key is given below to separate *Agistemus* mites infesting medicinal plants of West Bengal, India.

1 Propodosomal plate reticulate 2
– Propodosomal plate not reticulate 3
2 Ratio of setae ae/ae-ae more than 3 ..... *lobata*
– Ratio of setae ae/ae-ae less than 3 ..... *fleshneri*
3 Ratio of setae ae/ae-ae 1.5 or more 6
– Ratio of setae ae/ae-ae 1 or less than 1.5 4
4 Seta la and a almost equal 5
– Seta la considerably longer than a ..... *edulis*
5 Seta lm around 37 long and postocular body not so large ..... *terminalis*
– Seta lm around 17 long and postocular body large ..... *albae* sp.nov
6 Seta le only slightly shorter than e ..... *unguiparvus*
– Seta le reasonably shorter than e ..... *simplex*

ACKNOWLEDGEMENTS

We are thankful to the Ministry of Environment and Forests, Govt. of India (Sanction No. 14/26/2004 – ERS/RE) for financial assistance. We are also grateful to the Head, Department of Zoology, University of Calcutta for the facilities provided. Thanks are also due to CCF, Research Wing, Directorate of Forests, Government of West Bengal and Swami Vishwamayananda, Asst. Secretary, Ramakrishna Mission Ashrama, Narendrapur for kindly permitting us to carry out the work in their gardens.

REFERENCES

Childers C. C. (1994) Biological control of phytophagous mites on Florida citrus utilizing predatory arthropods. In: *Pest Management in the Subtropics: Biological Control –A Florida Perspective*, Rosen D., Bennet F. and Capinera J. (Eds). ndover, UK, 255–288.

Childers C. C. and Enns W. R. (1975) Field evaluation of early season fungicide substitutions on Tetranychid mites and the predators *Neoseiulus fallacis* and *Agistemus fleschneri* in two Missouri apple orchards. Journal of Economic Entomology, 68: 719–724.

Ghosh S. and Gupta S. K. (2003) A report on mites occurring on medicinal plants in West Bengal. Records of Zoological Survey of India, 101: 287–298.

Gonzalez-Rodriguez R. H. (1965) *University of California Publications in Entomology*, p. 64.

Gupta S. K. (2002) A Monograph on plant inhabiting predatory mites of India. Part I: Orders. Prostigmata, Astigmata and Cryptostigmata. Memoirs of the Zoological Survey of India, 19(2): p. 18.

Gupta S. K. (2005) *Insects and Mites Infesting Medicinal Plants in India*, Ramakrishna Mission Ashrama, Narendrapur, Kolkata, p. 214.

Lahiri S., Podder S., Saha G. K. and Gupta S. K. (2004) Diversity of phytophagous and predatory mites occurring on medicinal plants in Kolkata metropolis. Proceedings of zoological society, 57(1): 47–52.

Lahiri S., Roy I., Podder S., Saha G. K. and Gupta S. K. (2005) Notes on phytophagous and predatory mites of medicinal plants of Kolkata. Zoos' print journal, 20(7): 1931–1932.

Muma M. H. (1975) Mites associated with citrus in Florida. In: *Agricultural Experimentation Station Bulletin 640A*, IFAS, University Florida, Gainesville,USA, 92pp.

Nelson E. E., Croft B. A., Howitt A. J. and Jones A. L. (1973) Toxicity of apple orchard pesticides to *Agistemus fleschneri*. Environmental Entomology, 2: 219–222.9.

Roy I., Gupta S. K. and Saha G. K. (2006) Two new species of Prostigmatid mites infesting medicinal plants in West Bengal, India. Entomon, 31(4): 307–313.

Roy I., Gupta S. K. and Saha G. K. (2008a) A new species and a new record of phytoseiid mites infesting medicinal plants of West Bengal, India. Proceedings of zoological society, Kolkata, 61(1&2): 1–4.

Roy I., Gupta S. K. and Saha G. K. (2008b) New reports of predatory mites (Acari: Prostigmata, Mesostigmata) from medicinal plants of Darjeeling district, West Bengal, India with description of a new species. Entomon, 33(2): 119–128.

(Received 27 April 2009; accepted 15 August 2009)

ENTOMON 34(3): 181–184 (2010)
Short Communication No. ent.34307

Evidence of induced resistance against the Red spider mite, *Tetranychus urticae* Koch. in Okra (*Abelmoschus esculentus* (L.) Moench) plants manured with oilcake based vermicomposts

T. P. Mahto and R. P. Yadav

Department of Entomology & Agril. Zoology, Tirhut College of Agriculture (RAU, Pusa), Dholi, Muzaffarpur, Bihar 843 121, India
Email: rpyento@rediffmail.com
Email: rpyadavento@gmail.com

ABSTRACT: Rearing of the red spider mite, *Tetranychus urticae* Koch, on foliage of Okra (*Abelmoschus esculentus* (L.) Moench) plants manured with different oilcake based vermicomposts resulted in reduced reproductivity of the pest. Highest reduction was due to neem cake based vermicompost which was significantly superior to karanj and castor cake based vermicomposts. Lowest reduction was in vermicompost from cow dung alone but significantly higher than that in unmanured control. Reduction in reproductivity of *T. urticae* is indicative of induced resistance against it in host plants through manuring with oilcake vermicomposts.

KEYWORDS: *Tetranychus urticae*, Okra plants, vermicomposts, induced resistance

Okra plant, *Abelmoschus esculentus* (L.) Moench is one of the extensively grown vegetables in almost all parts of the country and the Red spider mite, *Tetranychus urticae* Koch, is one of the serious pests attacking this crop in summer season. To avoid or minimize the ill effects caused by chemical pesticides now being used extensively for controlling this pest, a meaningful change in the pest management strategy is needed. In this context, the mechanism of induced pest resistance in crop plants is gaining attention in recent years. It is the qualitative and quantitative enhancement of plant's defence mechanism and is a non-heritable resistance, where the host plants are induced to impart resistance to tide over pest infestation (Dilawari and Dhaliwal, 1993). Therefore, the possibility of induced resistance against *T. urticae* in Okra plants through application of different oil cake based vermicomposts was assessed.

A pot experiment in CRD with two replications for each treatment was conducted in summer season of 2004–05 and 2005–06, using oilcake based vermicomposts each at two different doses (vide Table 1). Each pot was filled with 8.0 kg of soil mixed with

measured quantity of different vermicomposts. The pots were watered to maintain the moisture at field capacity. After a lapse of one week, five seeds of Okra were sown in each pot and were maintained in the insectary. Leaf bits measuring 2.5 cm × 2.5 cm prepared from the leaves of pot cultured Okra plants in different treatments were kept separately on moist cotton swab in Petri plates of 5.0 cm diameter. A fertilized female deutonymph along with a male was released on each leaf bit in Petri plate separately. For each treatment, five sets of Petri plates were maintained. Adults emerged from the female deutonymphs were observed for egg laying every 24 h till they stopped laying eggs and died. Leaf bits when dried up were replaced by fresh ones from the respective treatment and observations continued. The eggs laid were allowed to hatch and data were recorded. After hatching, the crawlers were kept in separate Petri plates for recording adult emergence. Data pooled over the two years (2004–05 and 2005–06) were subjected to statistical analysis to test the significance of the difference among treatments.

The results are presented in Table 1. Mean number of eggs/female mite ranged from 49.17 to 69.17, lowest and highest being in vermicompost from cow dung+ neem cake (4:1) at 1.0 kg/pot and untreated control, respectively. Like fecundity, hatchability of eggs too was remarkably affected when reared on Okra plant manured with different vermicomposts. It ranged from 51.88% to 85.76%, lowest and highest being in case of manuring with vermicompost from cow dung + neem cake (4:1) at 1.0 kg/pot and untreated control, respectively. Differential effect of manuring with vermicomposts from cow dung alone and that from cow dung + oilcakes continued to follow up to adult emergence, which ranged from 46.38% to 77.77% in different treatments, lowest and highest being in case of manuring with vermicompost from cow dung + neem cake (4:1) at 1.0 kg/plot and untreated control, respectively. From the foregoing results, it is obvious that all the three biological parameters viz, fecundity, hatchability, and adult emergence in *T. urticae* were adversely affected by feeding on leaves of Okra plants manured with oilcake based vermicomposts. Different oil cakes showed varying degree of adverse effect, but mixing of neem cake with cow dung resulted in vermicompost that recorded relatively poor fecundity, hatchability and adult emergence in comparison to other vermicomposts or no compost.

Overall adverse effect exerted by manuring was finally adjudged on the basis of reproductivity i.e. number of progeny produced/female of *T. urticae*. It ranged from 11.83 to 46.14 progeny/female, lowest and highest being in case of manuring with vermicopost from cowdung + neem cake (4:1) at 1.0 kg/pot and unmanured control, respectively. Feeding of mites o.i leaves of plants grown on vermicopost from cowdung alone at 1.0 kg/pot yielded 39.67 progeny/ female compared to that on vermicomposts from cow dung + oilcakes (11.83–30.59 progeny/female). Mixing of neem cake with cow dung in 4:1 or 4.5:0.5 at application rate of 0.5–1.0 kg/pot, clearly proved superior to either Karanj or castor cake in reducing reproductivity of the Red spider mite. Between Karanj and castor cake, the latter proved inferior.

The results of this study thus indicate development of induced resistance against *T. urticae* in Okra plants due to manuring with cow dung + oil cakes (neem, karanj or

TABLE 1. Biological parameters of *Tetranychus urticae* reared on Okra plant manured with oilcake based vermicomposts

Organic substrates for vermicompost	Ratio (w/w)	Dose (kg/pot)	Number of eggs/female	Hatchability (%)	Adult Emergence (%)	Number of Number of progeny/female
Cow dung + neem cake	4.0 : 1.0	0.5	53.00(7.28)[a]	54.11(47.33)[b]	48.26(43.99)	13.84
		1.0	49.17(7.01)	51.88(46.05)	46.38(42.91)	11.83
	4.5 : 0.5	0.5	55.00(7.43)	57.71(49.41)	51.28(45.72)	16.28
		1.0	53.34(7.30)	56.89(49.01)	50.05(45.01)	15.19
Cow dung + castor cake	4.0 : 1.0	0.5	60.67(7.79)	67.32(55.12)	62.45(52.19)	25.50
		1.0	58.16(7.63)	65.06(53.75)	59. 91(50.70)	22.67
	4.5 : 0.5	0.5	61.00(7.81)	73.75(59.17)	67.99(55.52)	30.59
		1.0	59.00(7.68)	70.58(57.12)	65.42(53.96)	27.31
Cow dung + karanj cake	4.0 : 1.0	0.5	55.50(7.45)	60.91(51.28)	56.38(48.65)	19.05
		1.0	52.67(7.26)	57.85(51.26)	53.57(47.03)	16.32
	4.5 : 0.5	0.5	57.00(7.55)	64.60(53.45)	59.71(50.58)	21.98
		1.0	54.00(7.35)	61.72(51.77)	57.06(49.04)	19.02
Cow dung alone	–	0.5	64.84(8.05)	81.76(64.71)	70.60(57.20)	37.43
		1.0	63.17(7.95)	79.25(62.84)	70.36(57.00)	39.67
Control (Unmanured)	–	–	69.17(98.32)	85.76(64.27)	77.77(61.84)	46.14
CD ($P = 0.05$)			(0.12)	(3.16)	(1.78)	–

Values presented are pooled mean of 2004–05 and 2005–06. [a]Figures in parentheses are transformed values ($\sqrt{X}$). [b]Figures in parentheses are values of angular transformation

castor cakes) based vermicomposts, more particularly neem cake based vermicopost. Induced resistance against insects has also been reported in other crops (Rao, 2002; Kavitharaghavan *et al.*, 2006). The present findings would be helpful in improving the quality of vermicompost from pest management point of view, for organic vegetable production.

ACKNOWLEDGEMENTS

The senior author is grateful to the Rajendra Agricultural University, Bihar, Pusa (Samastipur) for providing support in the form of fellowship to pursue Ph.D research programme. Thanks are due to Associate Dean cum Principal, Tirhut College of Agriculture, Dholi, Muzaffarpur, Bihar for the facilities provided to carry out the experiments.

REFERENCES

Dilawari V. K. and Dhaliwal G. S. (1993) Host plant resistance to insects: Novel concepts. In: *Advances in Host Plant Resistance to Insects*, Dhaliwal G. S. and Dilawari V. K. (Eds). Kalyani Publishers, New Delhi, India, 393–422.

Rao K. R. (2002) Induced host plant resistance in the management of sucking insect pests of groundnut. Annals of Plant Protection Science, 10(1): 45–50.

Kavitharaghavan Z., Rajendran R. and Vijayaraghavan C. (2006) Effect of fertilizers applied to brinjal on host plant preference and development of sucking pests. Entomon, 31(2): 77–82.

(Received 5 January 2009; accepted 15 August 2009)

ENTOMON 34(3): 185–188 (2010)
Short Communication No. ent.34308

Evaluation of four fungal pathogens against *Dinoderus minutus* Fab. (Coleoptera: *Bostrychidae*), a post harvest pest of bamboo

R. F. Juliya*, R. V. Varma and Raju Paduvil

Forest Protection Division, Kerala Forest Research Institute, Peechi 680 653, Kerala, India
Email: juliyaranifrancis@yahoo.com
Email: varmarv@gmail.com

ABSTRACT: Efficacy of four entomopathogenic fungi, *Beauveria bassiana*, *B. brongniartii*, *Paecilomyces fumoso-roseus* and *Metarhizium anisopliae* isolated from different host insects were evaluated in the laboratory against adult *Dinoderus minutus* Fab. (Coleoptera: Bostrychidae). All the four fungi were pathogenic to *D. minutus*. The LC_{50} (8.7×10^5 conidia/ml) and LT_{50} (58.74 h) values showed that *B. brongniartii* was more virulent against *D. minutus* under laboratory conditions, followed by *B. bassiana*, *M. anisopliae* and *P. fumoso-roseus*.

KEYWORDS: Entomopathogenic fungi, *Beauveria bassiana*, *B. brongniartii*, *Paecilomyces fumoso-roseus*, *Metarhizium anisopliae*, *Dinoderus minutus*

Post-harvest pests are of concern in bamboo industry because of economic loss caused to bamboo in storage and finished products (Beeson, 1941; Nair *et al.*, 1983; Hidalgo-Lopez, 2003; Raju, 2008). *Dinoderus minutus* Fab. (Coleoptera: Bostrychidae) is considered the most important stored pest of bamboo. It is reported that about 40 per cent of the bamboo stack may be lost within a period of 8–10 months due to borer attack (Thapa *et al.*, 1992). Easily biodegradable fourth generation chemical insecticides have been proposed to control *Dinoderus* in harvested bamboo (Thakur and Bhandari, 1997). Technical advances in the production and use of entomopathogenic fungi has stimulated an interest in developing them as environmentally compatible biocides. In the present study, pathogenicity of four entomopathogenic fungi *viz.*, *Beauveria bassiana*, *B. brongniartii*, *Paecilomyces fumoso-roseus* and *Metarhizium anisopliae* were evaluated against the adults of *D. minutus*.

The stock culture of *D. minutus* was maintained in the laboratory on dried tapioca. *Beauveria bassiana* and *Paecilomyces fumoso-roseus* were isolated from lepidopteran

*Corresponding author

TABLE 1. Comparative efficacy of four fungi for control of *D. minutus*

Fungus	Slope ±SE[a]	X^2 value[b]	LC_{50} with 95% FL[c] (conidia/ml)
B. bassiana	1.74 ± 0.54	4.81	1.04×10^6 (1.07×10^5–1.90×10^6)
B. brongniartii	1.96 ± 0.64	4.28	8.7×10^5 (6.15×10^4–1.65×10^6)
P. fumoso-roseus	1.71 ± 0.44	4.19	3.70×10^6 (2.25×10^6–4.91×10^6)
M. anisopliae	1.55 ± 0.45	4.53	1.88×10^6 (4.92×10^5–2.90×10^6)

[a]Standard error. [b]Goodness of fit test: table entries are not significant at the level of $p > 0.10$ ($df = 11$). [c]Fiducial limits.

hosts (Hesperiidae and Pyralidae, respectively) from Nilambur. *B. brongniartii* was isolated from a coleopteran (Chrysomelidae) from Vazhani; and *Metarhizium anisopliae*, from a hemipteran (Pentatomidae) from Konni, all places situated in Kerala. The fungi were maintained in the laboratory on Potato-Dextrose-Agar-Yeast extract (PDA-Y) medium at 25 ± 1 °C, 80 ± 2% RH, and 12:12 (L: D) photoperiod. Conidial suspension of each fungus was prepared from 14-day old cultures using sterile distilled water. Tween 20 (0.1%) was used as the wetting agent.

For treatment, ten adult beetles were placed in a Petri-dish (10 cm dia) and 100 μl of the fungal inoculum was sprayed onto the beetles using a standard atomizer. A control sprayed with sterile water was also maintained. The treated beetles were allowed to remain in the Petri-dish for 2 min and then transferred to another sterile Petri-dish containing dried tapioca. Three replicates were maintained for each concentration and each replicate had ten insects. Treated beetles were maintained at 25 ± 1 °C, 80 ± 2% RH, and 12:12 (L: D) photoperiod. Mortality of the beetles was recorded at 12 h interval. Randomly selected cadavers were surface sterilized, incubated for 3–4 days, plated on PDA-Y medium and examined under the microscope to confirm the presence of the test fungus. Data were pooled and subjected to probit analysis and LC_{50} and LT_{50} were determined. Software POLO (© (Le Ora Software, 1987), based on Finney (1971) was used for analyzing data.

Mortality started 48 h after treatment and reached its peak at 84–120 h. Mortality of beetles was not observed in the controls. Data on sixth day were used in the probit analysis. There was a good linear relationship between probit transformed mortality data and $\log_{10}$ transformed concentrations. χ^2 test for heterogeneity about the regression of each bioassay was insignificant at the level of $p > 0.10$ (Table 1). Because of the favourable regression, 95 per cent fiducial limits of the response doses were computed using a t value of 1.96.

All the four fungi tested were pathogenic to *D. minutus* under laboratory conditions. Difference in the virulence of the fungi to *D. minutus* was compared using LC_{50} and

TABLE 2. LT_{50} values of four fungi on *D. minutus* at different concentrations of conidial suspension

F	LT_{50} (h), with fiducial limits, at dose (conidia/ml)				
	2×10^6	4×10^6	6×10^6	8×10^6	1×10^7
Bb	105.83 (100.4–112.2)	103.72 (99.0–108.8)	98.32 (93.7–103.2)	93.79 (87.3–101.4)	88.26 (83.2–93.5)
Bbr	93.66 (88.3–99.4)	89.59 (84.2–95.2)	82.46 (77.7–87.1)	70.99 (66.3–75.5)	58.74 (54.1–63.1)
Pf	138.98 (126.7–166.9)	125.67 (118.5–137.8)	123.83 (117.8–133.4)	107.54 (102–114.2)	95.51 (90.8–100.4)
Ma	119.18 (111.8–130.3)	112.27 (106.3–120.2)	99.66 (94.4–105.4)	94.75 (90.4–99)	90.28 (86.3–94.3)

F, Fungus; *Bb*, *B. Bassiana*; *Bbr*, *B. Brongniartii*; *Pf*, *P. Fumosoroseus*; *Ma*, *M. anisopliae*

LT_{50} values. Least LC_{50} value was obtained for *B. brongniartii* (8.7×10^5 conidia/ml) followed by *B. bassiana* (1.04×10^6 conidia/ml) and the highest LC_{50} value was obtained for *P. fumoso-roseus* (3.70×10^6 conidia/ml) (Table 1).

LT_{50} values obtained for the four fungi are given in Table 2. The shortest LT_{50} was obtained for *B. brongniartii* (93.66 h to 58.74 h, from the lowest to the highest dose tested), followed by *B. bassiana* (105.83 h to 88.26 h), *M. anisopliae* (119.18 h to 90.28 h) and *P. fumoso-roseus* (138.98 h to 95.51 h).

Among the pathogens tested, the coleopteran isolate, *B. brongniartii* was found to be more virulent against *D. minutus*, with low LC_{50} and short LT_{50} values. This is probably because the pathogen is pre-adapted to a coleopteran host. The scope of using *B. brongniartii* as a promising fungal pathogen for control of the cockchafer *Melolontha melolontha* L. (Coleoptera: Scarabaeidae) under laboratory and field conditions was reported earlier (Ferron, 1978; Keller *et al.*, 2001; Vestergaard *et al.*, 2002). The effectiveness of *B. bassiana* and *M. anisopliae* against adult Japanese beetle, *Popillia japonica* (Coleoptera: Scarabaeidae) under laboratory conditions was also reported (Lecey *et al.*, 1994). A strain of *B. brongniartii* isolated from the yellowish elongate chafer, *Heptophylla picea* (Coleoptera: Scarabaeidae) caused 100 per cent mortality in adults of *H. picea* with a concentration of 1×10^7 conidia/ml (Yaginuma *et al.*, 2006). The LT_{50} values obtained for females and males of *H. picea* were 8.4 and 7 days, respectively. Pathogenicity of *B. bassiana* and *M. anisopliae* to *Calopepla leayana* (Coleoptera: Chrysomelidae) and *Myllocerus viridanus* (Coleoptera: Curculionidae) with greater susceptibility to *B. bassiana* was reported from India (Sankaran *et al.*, 1989; Singh *et al.*, 2002). The present study has shown the potential of coleopteran derived isolate of *B. brongniartii* as a promising biocontrol agent against *D. minutus*.

ACKNOWLEDGEMENT

The financial support received from Ministry of Environment and Forests, Government of India to carry out the work is duly acknowledged.

REFERENCES

Beeson C. F. C. (1941) *The Ecology and Control of the Forest Insects of India and the Neighboring Countries*, Government of India, p. 720.

Ferron P. (1978) Biological control of insect pests by entomogenous fungi. Annual Review of Entomology, 23: 412–418.

Finney D. J. (1971) *Probit Analysis, 3rd Edition*, Cambridge University Press, London, England, p. 318.

Hidalgo-Lopez O. (2003) *Bamboo: The Gift of God*, Oscar Hidalgo, Colombia, p. 553.

Keller S., Kessler P., Jensen D.B., Schweizer C. and Keller S. (2001) How many spores of *Beauveria brongniartii* are needed to control *Melolontha melolontha*? *Proceedings of the IOBC WPRS Working Group Meeting on Integrated Control of Soil Pest Melolontha*. Aosta, Italy, 24-26 September, 2001. Bulletin- OILB-SROP, 25(7): 59–63

Lecey L. A., Ma A. and Ribeiro C. (1994) The pathogenicity of *Metarhizium anisopliae* and *Beauveria bassiana* for adults of the Japanese beetle, *Popillia japonica* (Coleoptera: Scarabaeidae). European Journal of Entomology, 91: 313–319.

Nair K. S. S., Mathew G., Varma R. V. and Gnanaharan R. (1983) *Preliminary investigations on the biology and control of beetles damaging stored reed* KFRI Research Report No. 19, KFRI, Peechi, Kerala, India, p. 35p.

Raju Paduvil (2008) Post harvest damage by *Dinoderus* beetle in bamboos and its management. In: *Ph.D. Thesis* submitted to Forest Research Institute University, Dehra Dun, Uttaranchal, p. 104.

Sankaran K. V., Mohanadas K. and Mohammed Ali M. I. (1989) *Beauvaria bassiana* (Bals.) Vuill., a possible biocontrol agent of *Myllocerus viridianus* Fabr. and *Calopepla leayana* L. in South India. Current Science, 58(8): 467–469.

Singh S, Barman H. K., Barthakur N. D. and Singh S. (2002) Pathogenicity of entomogenous fungi on *Calopepla leayana* (Coleoptera: Chrysomelidae), a major insect pest of Gamhar, *Gmelina arborea*. Annals of Forestry, 10(2): 351–355.

Thakur M. L. and Bhandari R. S. (1997) Recent trends in protection of harvested bamboos from ghoon borers. Indian Forester, 123(7): 646–651.

Thapa R. S., Singh P. and Bhandari R. S. (1992) Prophylactic efficacy of various insecticides for the protection of bamboos in storage against ghoon borers, *Dinoderus* sp. Journal of Academy Wood Science, 23(1).

Vestergaard S., Nielsen C., Harding S., Eilenberg J. and Keller S. (2002) First field trials to control *Melolontha melolontha* with *B. brongniartii* in Christmas trees in Denmark. In:*Proceedings of the IOBC-WPRS working group meeting on Integrated Control of Soil Pest Melolontha*Aosta, Italy, 24-26 September, 2001. Bulletin- OILB-SROP, 25(7): 51–58.

Yaginuma D., Hiromori H. and Hatsukade M. (2006) Virulence of the entomopathogenic fungus *Beauveria brongniartii* to several life stages of the yellowish elongate chafer *Heptophylla picea* Motschulsky (Coleoptera: Scarabaeidae). Applied Entomology and Zoology, 41(2): 287–293.

(Received 7 March 2009; accepted 15 August 2009)

ENTOMON 34(3): 189–192 (2010)
Short Communication No. ent.34309

Biology of the mealy bug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Psuedococcidae) on cotton in India

Rishi Kumar*, Shravan Lal Jat, Vijander Pal and Rahul Chauhan

Central Institute for Cotton Research, Regional Station, Sirsa 125 055, Haryana, India
Email: rishipareek70@yahoo.co.in

ABSTRACT: *Phenacoccus solenopsis* Tinsley (Hemiptera: Psuedococcidae) reported on cotton in India in 2007 is an exotic species originally described from USA in 1898. The oblong shaped, wingless female of *P. solenopsis* laid eggs in uniformly secreted ovisac covered under its body. The mean number of ovisacs per female was 2.9. The mealy bug is a prolific breeder and produced a mean of 390.7 crawlers per female on cotton. The female has three nymphal instars whereas the male has two nymphal instars and a pupal stage (cocoon). The 1st and 2nd nymphal instars of male and female are indistinguishable. The 1st instar nymph (crawler) showed high motility and had no permanent feeding site. The mean total nymphal duration of male was 23 d and of female, 24.6 d. The mean longevity of male was 1.2 d and of female, 16.9 d. The population of *P. solenopsis* had a positive correlation with temperature.

KEYWORDS: *Phenacoccus solenopsis*, development, biology

Until 2007, there has been no published evidence of occurrence of mealy bug (Hemiptera: Pseudococcidae) on *Gossipium hirsutum* (Linn.) which currently occupies over 80% of the total cotton cultivated area in India although there were isolated reports of occurrence of *Maconellicoccus hirsutus* (Green) on the native cotton, *Gossypium arboreum* (Dhawan *et al.*, 1980) and the new world cotton, *G. herbaceum* (Murlidharan and Badaya, 2000). But during 2007, mealy bug infestation was recorded in all nine cotton growing states of India, and taxonomic study showed that two species, *Maconelicoccus hirsutus* and *Phenacoccus solenopsis* were involved. *P. solenopsis* which was not reported earlier from India was found as the predominant species. It is an exotic species introduced from USA (Nagrare *et al.*, 2009).

P. solenopsis is a known pest of ornamental and fruit trees world wide. Its first report on cotton was published in the USA in 1991 (Fuchs *et al.*, 1991). Subsequently it was reported from Pakistan in 2006 and from Gujarat, followed by Punjab and

*Corresponding author

TABLE 1. Biological parameters of *Phenacoccus solenopsis*

Parameter	Mean ± SE
Instar I, duration (days)	4.80 ± 0.25
Instar II, duration (d)	4.90 ± 0.28
Pupa, male, duration (d)	13.30 ± 0.42
Instar III, female, duration (d)	14.90 ± 0.51
Adult longevity, male (d)	1.20 ± 0.07
Adult longevity, female (d)	16.90 ± 0.53
Pre-oviposition period (d)	5.00 ± 0.26
Oviposition period (d)	5.80 ± 0.39
Post-oviposition period (d)	4.50 ± 0.34
Total crawlers/female (No.)	390.70 ± 25.89
Ovisac/female (No.)	2.90 ± 0.23

Values given are the mean and standard error of 10 replicates.

Haryana in India (Monga *et al.*, 2009). Information on the biology and development of *P. solenopsis* is scanty. In the present study an attempt was made to understand its biology on cotton in India as it would be useful in Integrated Management of this pest.

Observations on biology were made under polyhouse conditions during July (peak of cotton season). Ten ovisacs obtained from *P. solenopsis* reared on potted cotton plants were placed separately on 10 cotton plants of one month age (one ovisac/plant). The ovisacs were removed after 24 h and observations were recorded on the development of the crawlers that were released from the ovisac and settled on the cotton plants during the 24 h period. The number and interval between moulting were carefully noted. Fecundity was studied by leaving one crawler on a potted plant (10 replications) till the formation of ovisacs by the females and counting the number of crawlers emerging from the ovisacs. To study the mode of reproduction, two sets of 10 third instar females were removed from cotton plants and reared on potato sprouts, one set with males and one set without.

The effect of temperature, humidity and rainfall on the development of the mealybug was studied by recording weekly the mealybug population from 10 fixed locations. The number of mealybugs from 5 cm length of the central shoot of 10 plants was counted.

Table 1 shows the biological parameters of *P. solenopsis*.

The adult female is nymph-like, oblong, and light to dark grey greenish, with two black stripes on the dorsal side of the abdomen. Survival percentage from 3rd nymphal instar to the adult stage was 89.1%. This stage lasted from 14 to 19 days (mean 16.9 d).

Eggs were not observed as they remain in ovisac. The 1st instar and early 2nd instar females are not distinguishable from the males and both are oblong in shape. The 1st instar (crawler) is yellow greenish in color, with a pair of seven- to eight-segmented antennae. It preferred the apical portion of the plant but infestation was noticed on other parts like leaves, petioles, squares and bolls. This stage was the most active as

it lacked mealy wax secretion, and responsible for dispersal of the bugs. The mean duration of this stage was 4.8 days. The survival percentage from the 1st to 2nd instar was 69.32. The 2nd instar female is oblong and grey greenish, with seven-segmented antennae. The tip of the abdomen is protruded and has two setae. This stage lasted for 4.9 days. The 3rd instar female is grey greenish in colour and oblong in shape. At this stage white cottony substance appears and covers the entire body. The antennae are straight, filiform and 7-segmented. The mean duration of this stage is 14.9 d with survival percentage of 74.16. Formation of puparium was not observed in the case of female.

The male of *P. solenopsis* has a pair of wings and long waxy caudal filaments (cerci). It is short lived with longevity of 1.2 days. Survival percentage from pupa to the adult male was 83.12%. The males were not available throughout the year. In 2007, the males were observed in the month of October whereas in 2008 they were observed in August.

As noted earlier, the 1st and 2nd instar males are not distinguishable from the female. At the end of 2nd instar (from 8th to 12th day of nymphal life) formation of puparia (cocoon) started. The pupal stage has two small wing buds, one on each side of the mesothorax. The mean duration of the pupal stage was 13.3 days. The survival percentage from 2nd instar to pupa was 61.2.

In experiments in which adult female mealy bugs were kept with and without male to study reproduction, occurrence of both sexual and asexual reproduction was confirmed. In the case of asexual reproduction only female offsprings were produced. Only asexual reproduction was recorded during the active growth season of cotton (May to August).

The mealybug population ranged from 59.6 insects per 5 cm central shoot in May to nil in October. The population build up had a significant positive correlation with temperature. Akintola and Ande (2008) recorded the total duration of developmental stage of *P. solenopsis* as 24 days. In the present study it was 23 days in male and 24.6 days in female.

ACKNOWLEDGEMENT

The facilities provided by Head, CICR for conducting this study are gratefully acknowledged.

REFERENCES

Akintola A. J. and Ande A. T. (2008) First record of *P. solenopsis* Tinsley (Hemiptera: Pseeudococcidae) on *Hibiscus rosa sinensis* in Nigeria. Agricultural Journal, 3(1): 1–3.

Dhawan A. K., Singh J and Sindhu A. S. (1980) *Maconellicoccus* sp attacking *Gossypium arboreum* cotton in Punjab. Science and Culture, 46: 258.

Fuchs T. W,, Stewart J. W., Minzenmayer R. and Rose M. (1991) First record of *Phenacoccus solenopsis* Tinsley in cultivated cotton in the United States. Southwestern Entomologist, 16(3): 215–221.

Monga D., Rishi Kumar M. C., Vijendra Pal and Jat (2009) Mealybug, a new pest of cotton crop in Haryana,-a survey. Journal of Insect Science, 22(1): 100–103.

Murlidharan C. M. and Badaya S. N. (2000) Mealybug (Maconellicoccus hirsutus) (Pseudococcidae: Hemiptera) outbreak on herbaceum cotton in Waged cotton belt of Kachchh. Indian Journal of Agricultural Sciences, 70: 705–706.

Nagrare V. S., Kranthi S., Biradar V. K., Zade N. N., Sangode V., Kakde G., Shukla R. M., Shivare D., Khadi B. M. and Kranthi K. R. (2009) Widespread infestation of the exotic mealybug species, Phenacoccus solenopsis (Tinsley) (Hemiptera: Pseudococcidae) on cotton in India. Bulletin of Entomological Research, 1–5.

(Received 2 March 2009; accepted 15 August 2009)

ENTOMON 34(3): 193–195 (2010)
Short Communication No. ent.34310

Green clover worm, *Plathypena scabra* (Fab.) (Lepidoptera: Noctuidae), a new emerging pest of soybean in southern Rajasthan

M. M. Kumawat[1] and Ashok Kumar[1,2]

[1] *Department of Plant Protection, College of Horticulture and Forestry, Central Agricultural University, Pasighat 971 102, Arunachal Pradesh, India*
[2] *Department of Entomology, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur 313 001, Rajasthan, India*
Email: kumawatmm@gmail.com

ABSTRACT: A low level infestation of the Green clover worm, *Plathypena scabra* was recorded on soybean in four districts of southern Rajasthan in 2004 and 2005. This is the first report of this pest on soybean in India.

More than 200 insect pests have been reported infesting soybean, *Glycine max* (L.) Merrill at various growth stages of the crop in India (Singh and Singh, 1990). Joshi (1987) reported a total of 31 insect pests in soybean crop from Rajasthan, including six lepidopterans. For the first time, we found the Green clover worm, *Plathypena scabra* (Lepidoptera: Noctuidae) infesting this crop in Rajasthan. This pest was not recorded previously from India. The type location of *P. scabra* is located in North America and its major food plants are beans, clover, alfalfa and strawberry (Poole, 1989). A study was undertaken to record the seasonal incidence of *P. scabra* in soybean crop in southern Rajasthan.

The survey was made during the *kharif* season in 2004 and 2005, at Mewar-Vagar region of Rajasthan in eight tehsils of four districts, viz., Dhariyawad and Salumber in Udaipur district, Pratapgarh and Chhoti Sadri in Chittorgarh district, Banswara and Ghatol in Banswara district, and Sagwara and Aspur in Dungarpur district. Five farmer's fields in which the soybean crop was not sprayed with insecticides were selected randomly in each tehsil. At 15 days interval during the crop season, five plants were selected in each field and observation was made on the presence of the insect pest.

During 2004, the infestation of *P. scabra* started in the third week of July with a mean (mean of eight sampled sites) of 0.061 larvae per plant which consistently increased, reaching its peak of 0.73 larvae per plant in the second week of September (Table 1. Thereafter, a decrease in population was recorded towards crop maturity.

TABLE 1. Population abundance of *Plathypena scabra* in different areas of southern Rajasthan

Survey period	No. of insects per plant															
	Dhariyawad		Salumber		Chhoti sadri		Pratapgarh		Banswara		Ghatol		Sagwara		Aspur	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
2–8 July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16–22 July	0.0	0.04	0.20	0.0	0.08	0.04	0.0	0.12	0.04	0.0	0.0	0.0	0.04	0.0	0.12	0.08
30 July–5 Aug	0.12	0.20	0.60	0.24	0.16	0.24	0.16	0.36	0.32	0.32	0.12	0.16	0.12	0.20	0.40	0.32
13–19 Aug	0.20	0.28	0.88	0.80	0.26	0.36	0.36	0.68	0.56	0.16	0.40	0.56	0.36	0.40	0.60	0.88
27 Aug–2 Sept	0.36	0.44	1.04	0.96	0.48	0.40	0.48	0.96	0.72	0.56	0.60	0.88	0.40	0.76	0.88	1.48
10–16 Sept	0.52	0.48	0.72	1.40	0.32	0.28	0.96	1.28	0.84	0.96	0.76	0.96	0.48	0.16	1.24	0.96
24–30 Sept	0.14	0.24	0.40	0.44	0.12	0.08	0.80	1.08	0.40	1.40	0.56	0.12	0.24	0.12	0.76	0.52
8–14 Oct	0.12	0.08	0.04	0.12	0.04	0.0	0.36	0.24	0.12	0.24	0.12	0.0	0.08	0.0	0.12	0.08
22–28 Oct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean	0.16	0.20	0.43	0.44	0.16	0.15	0.35	0.52	0.33	0.40	0.28	0.30	0.19	0.18	0.46	0.48

During the peak period of incidence, infestation was noted at all the sampled sites, with a maximum of 1.24 larvae per plant at Aspur and a minimum of 0.32 larvae per plant at Chhotisadri. During 2005 also the infestation started in the third week of July and reached its peak in the second week of September, with 0.81 larvae per plant and then declined. During the peak infestation of 2005, a maximum of 1.4 larvae per plant was found at Salumber and a minimum of 0.16 larvae per plant at Sagwara.

ACKNOWLEDGEMENTS

We are thankful to Dr. V. V. Ramamurthy, National Pusa Collection, Division of Entomology, Indian Agricultural Research Institute, New Delhi, the Zonal Director of Research, Agricultural Research Station, Banswara and the Dean, Rajasthan College of Agriculture, Udaipur for providing the necessary facilities.

REFERENCES

Joshi F. L. (1987) Qualitative and quantitative survey of pest fauna and management of major lepidopteran pests of soybean, *Glycine max* (L.) Merrill *Ph.D. Thesis* submitted to Rajasthan Agricultural University, Bikaner, Rajasthan.

Poole R. W. (1989) *Lepidopterorum Catalogus (new series)*, Heppner J. B. (Ed). Fasc. 118 Noctuidae: Part II. E.J.Brill/Flora & Fauna Publications, New York, 501–1013.

Singh O. P. and Singh K. J. (1990) Insect pests of soybean and their management. Indian Farming, 39: 9–14.

(Received 10 June 2009; accepted 15 August 2009)

ENTOMON 34(3): 197–200 (2010)
Short Communication No. ent.34311

Native parasitoids of eucalyptus gall wasp, *Leptocybe invasa* (Fisher & LaSalle) (Eulophidae: Hymenoptera) and implications on the biological control of the pest

A. S. Vastrad*, K. Basavanagoud and N. Kavitha Kumari

Department of Agricultural Entomology College of Agriculture, University of Agricultural Sciences, Dharwad 580 005, India
Email: vastrad_v@yahoo.com
Email: asvastrad@gmail.com

ABSTRACT: Several hymenopteran parasitoids emerged from eucalyptus plant material infested by the gall wasp, *Leptocybe invasa* (Fisher & LaSalle), collected during October 2008. These include *Aprostocetus gala* Walker and *Aprostocetus* sp. (Eulophidae), *Megastigmus* sp. (Torymidae) and *Parallelaptera* sp. (Mymaridae). The extent of combined parasitization ranged from 49 to 74 per cent on severely infested early stage galls (2nd and 3rd). Among the parasitoids, *Megastigmus* sp. was the most dominant (90.74%) followed by *Aprostocetus* sp. (6.52%) and *A. gala* (2.72%).

Unknown in the world until 2000, the eucalyptus gall wasp, *Leptocybe invasa* (Fisher & LaSalle) (Eulophidae: Hymenoptera) has incredible natural dispersal ability throughout the areas where it has been introduced. It causes galls on the midribs, petioles and stems of new shoots of *Eucalyptus*. Heavy infestation leads to deformed leaves and shoots, and reduction in growth. Adult female ranges in size from 1.1 to 1.4 mm. The wasps lay eggs inside tender leaves and stem and the larvae after hatching remain in a cavity formed within the plant tissues and feed on the plant causing formation of galls. The pest attack was observed in nurseries, coppice shoots and young plantations. The affected seedlings show stunted growth and become unsuitable for planting (Mendel *et al.*, 2004). The practice of raising nursery for planting new areas coupled with coppicing provides large amounts of young leaf and shoot material ideal for *L. invasa* attack, favouring large population build-up and consequent higher levels of damage.

First noticed in India during 2001, the insect attack has assumed great significance since it has spread to many parts of the country. The infestation is very severe in

*Corresponding author

many parts of Karnataka where entire nurseries and vast areas of coppice have been destroyed. Gall wasp has thus become a major constraint in *Eucalyptus* production threatening the productivity of paper and rayon industry. No effective control measures exist to manage *L. invasa*. Biological control is the only feasible way to manage the pest over large areas. In Australia parasitoids play a significant role in regulating the populations of *L. invasa* (Kim *et al.*, 2008). The biological control agents of *L. invasa* are currently under quarantine test in Israel and efforts are also being made to import these parasitoids for classical biological control in India. In the light of the concerns raised on the risks of classical biological control (Samways 1997; Thomas and Willis, 1998) there is a need for caution before rushing into importation of exotic natural enemies. We report here the occurrence of several native parasitoids on *L. invasa* from India.

During a routine survey in 2008 to document the seasonal incidence of natural enemies of the pest infested plant material, several hymenopteran parasitoids were obtained. These include *Aprostocetus gala* Walker and *Aprostocetus* sp. (Eulophidae), *Megastigmus* sp. (Torymidae), *Parallelaptera* sp (Mymaridae) and *Telenomus* sp. (Platygasteridae). The extent of combined parasitization ranged from 49 to 74 per cent on severely infested early stage galls (2nd and 3rd). However, no parasitoids emerged from the fresh galls (1st stage), low or moderately infested coppice and nursery seedlings. Among the parasitoids, *Megastigmus* sp. was the most dominant (90.74%), followed by *Aprostocetus* sp. (6.52%) and *A. gala* (2.72%). Among the several hundreds of parasitoids collected, only one individual each belonged to *Telenomus* sp. and *Parallelaptera* sp. Occurrence of *Megastigmus* sp. and *Aprostocetus* spp as larval pupal parasitoids of *L. invasa* has been reported by other workers (Kim *et al.*, 2008). Native *Megastigmus* species are known to parasitize *L. invasa* in Italy, Turky and Isreael (Viggiani *et al.*, 2000; Protasov *et al.*, 2008). It is reported that *Megastigmus* species was not originally associated with *Eucalyptus* pests, but being local species it has adapted to develop on *L. invasa*. However, the question of local hosts of these *Megastigmus* species is still open (Protasov *et al.*, 2008). Two species of Mymaridae as parasitoids of another invasive gall wasp *Ophelimus maskelli* (Ashmead) has been reported from Australia. This is the first record of a species of Mymaridae reared as a larval parasitoid of a holometabolous insect. One or both of the *Stethynium* species are being considered for introduction into Israel for biological control of this pest. Mymarids are parasitoids in eggs of Cicadellidae or Membracidae; however, they also attack hosts that induce small round or blister type galls resembling insect eggs (Huber *et al.*, 2006). Similarly, *Telenomus* Haliday which is an egg parasitoid attacking a wide range of insects belonging to Lepidoptera, Neuroptera, Diptera and Heteroptera may develop from galls resembling eggs. Alternatively, *Telenomus* sp. recorded in the present study might have emerged from lepidopteran/heteropteran egg attached to the galled plant material kept for adult emergence. The status of *Telenomus* sp. as a natural enemy of *L. invasa* needs to be confirmed.

During subsequent surveys these parasitoids were recorded from the same location (Kulwalli, MSL 899 m, 15°21′ 95″N, 74° 48′ 07″E) and surrounding areas (Daddika-

malapur, Vaddarhatti and Prabhunagar) located within 25 km radius. Occurrence of *Aprostocetus* spp on *L. invasa* is a new host record from India and a new distribution record for Karnataka as confirmed from the Universal Chalcidoidea Database (Noyes, 2007). *Megastigmus viggianii* Narendran and Sureshan has been recorded earlier from Karnataka on eucalyptus galls (Gupta and Poorani, 2008). Several *Megastigmus* sp. and *Aprostocetus* sp. on different hosts have been recorded from India (Narendran *et al.*, 2007).

The literature is replete with many examples of native parasitoids exploiting the exotic hosts (Aebi *et al.*, 2006; Cooper and Rieske, 2007). In the light of increasing evidence of non-target host use and resultant threat to native biodiversity associated with it, the classical biological control needs to be weighed carefully (Louda *et al.*, 2003). Many exotic species have been released without considering the use of native species (van Lantern *et al.*, 2006). Past experiences have shown that the initial severity of invasive pests has been halted due to a combination of biotic and abiotic factors. While efforts are being made to introduce exotic natural enemies, the present findings may hold a key towards biological control of the invasive pest by native parasitoids, a logical way to reduce the risks of releasing exotic species. Further work on these native parasitoids is in progress.

ACKNOWLEDGEMENTS

This study was undertaken with financial assistance from The West Coast Paper Mills, Dandeli. We are grateful to Prof T. C. Narendran Trust for Animal Taxonomy, Calicut for identification of the parasitoids and Dr. Sanjay Tripathi, General Manager (Plantations), WCPM, Dandeli, for his cooperation in carrying out the study.

REFERENCES

Aebi A., Schonrogge K., Melika G., Alma A., Bosio G. and Quacchia A. (2006) Parasitoid recruitment to the globally invasive chestnut gall wasp, *Dryocosmus kuriphilus*. In: *Galling Arthropods and Their Associates: Ecology and Evolution*, Ozaki K., Yukawa J., Ohgushi T and Price P. W. (Eds). Springer, Japan, 103–121.

Cooper W. R. and Rieske L. K. (2007) Community associates of an exotic gall maker, *Dryocosmus kuriphilus* (Hymenoptera: Cynipidae) in eastern North America. Annals of Entomological Society of America, 100: 236–244.

Gupta A. and Poorani J. (2008) New distribution and host records of Chalcidoidea (Insecta: Hymenoptera) from various parts of India. Check List, 4(4): 410–414.

Huber J., Mendel Z., Protasov A. and La Salle J. (2006) Two new Australian species of *Stethynium* (Hymenoptera: Mymaridae), larval parasitoids of *Ophelimus maskelli* (Ashmead) (Hymenoptera: Eulophidae). Journal of Natural History, 40(32–34): 1909–1921.

Kim I. K., Mendel Z., Protasov A., Blumberg D. and La Salle J. (2008) Taxonomy, biology, and efficacy of two Australian parasitoids of the eucalyptus gall wasp, *Leptocybe invasa* Fisher & La Salle (Hymenoptera: Eulophidae: Tetrastichinae). Zootaxa, 1910: 1–20.

Louda S. M., Pemberton R. W., Johnson M. T. and Follet P. A. (2003) Nontarget effects — The Achilles' heel of biological control? Retrospective analyses to reduce risk associated with biocontrol introductions. Annual Review of Entomology, 48: 365–396.

Mendel Z., Protasov A., Fisher N. and La Salle J. (2004) Taxonomy and biology of *Leptocybe invasa* gen. & sp. n. (Hymenoptera: Eulophidae), an invasive gall inducer on eucalyptus. Australian Journal of Entomology, 43(2): 101–113.

Narendran T. C., Santhosh S. and Sudheer K. (2007) Biosystematics and biogeography of oriental Chalcidoidea (Hymenoptera) associated with plant galls. Oriental Insects, 41: 141–167.

Noyes J. S. (2007) Universal Chalcidoidea database. `http://internt.nhm.ac.uk/jdsml/perth/chalcidoids`(captured on 25 November 2007

Protasov A., Doganlar M., La Salle J. and Mendel Z. (2008) Occurrence of two local *Megastigmus* species parasitic on the Eucalyptus gall wasp *Leptocybe invasa* in Israel and Turkey. Phytoparasitica, 36(5): 449–459.

Samways M. J. (1997) Classical biological control and biodiversityconservation: what risks are we prepared to accept?. Biodiversity and Conservation, 6: 1309–1316.

Thomas M. B. and Willis A. J. (1998) Biocontrol-risky but necessary?. Trends in Ecology and Evolution, 13: 325–329.

van Lantern J. C., Bale J., Bigler F., Hokkenen H. M. T. and And Loomans A. J. M. (2006) Assessing risks of releasing exotic biological control agents of arthropod pests. Annual Review of Entomology, 51: 609–634.

Viggiani G., Loudonia S. and Bernardo U. (2000) The increase of insect pests in eucalyptus. Infornatore-Agrario, 58(12): 86–87.

(Received 13 May 2009; accepted 15 August 2009)

ENTOMON **34(3):** 201–204 (2010)
Short Communication No. ent.34312

Cleonaria bicolor Thomson (Coleoptera: Cerambycidae): a new pest of *Ixora*

K. D. Prathapan[1], M. H. Faizal[1] and K. N. Anith[2]

Department of Entomology, Kerala Agricultural University, Vellayani P O, Thiruvananthapuram 695 522, Kerala, India
[2]Department of Microbiology, Kerala Agricultural University, Vellayani P O, Thiruvananthapuram 695 522, Kerala, India
Email: prathapankd@gmail.com

ABSTRACT: The univoltine longhorn beetle *Cleonaria bicolor* Thomson is reported as a new pest of *Ixora* from India. Information on the natural history and host plants of *C. bicolor* is provided for the first time.

KEYWORDS: India, *Cleonaria bicolor*, *Ixora*, *Gardenia*, new pest

Species of *Ixora* (Rubiaceae) are tropical ornamental shrubs popular for the beauty of their flowers as well as foliage. The genus in Kerala comprises 21 native species (Nayar *et al.*, 2006). Serious infestation by the longhorn beetle *Cleonaria bicolor* Thomson (Coleoptera: Cerambycidae) has been observed on *Ixora* spp. in Kerala for the past three years. Other longhorn beetles recorded on *Ixora* in India are *Xylotrechus quadripes* Chevrolat (Beeson and Bhatia, 1939) and *Dihamus admixtus* Gahan (Mathur and Singh, 1960). The genus *Cleonaria* is represented by three species from the Oriental region. *C. bicolor* was described by Thomson in 1864 from Thailand. Gahan (1901) recorded its occurrence in the Nilgiri Hills in south India. Adult (Fig 1a) is 0.9 to 1.4 cm long with pubescent bright red brown dorsum. General colour of antenna, eye, legs and ventral side is black. Antenna is filiform, distinctly hairy and extends slightly beyond middle of the elytra over pronotum. Two consecutive life cycles of the beetle were observed in the field at the College of Agriculture campus, Vellayani, Trivandrum District, Kerala (76°34′27″ E, 9° 21′46″ N) during 2006–08. *C. bicolor* is univoltine and emergence of the adults coincides with summer rains when the plant starts to put forth new flushes, providing ample food. The first adult emerged from the infested stems kept in the laboratory on 5th March 2007 following rains on 2nd and 3rd March. In 2009, the place received the first summer rain of 9.8 mm on 13th March and a single newly emerged adult was noticed on 15th March in the field. Last adult in Trivandrum in 2007 was observed on 13th July. Beetles were common on the plants during May-June. They feed on the underside of young

FIGURE 1. a. *Cleonaria bicolor*; b. adult; c. oviposition hole; d. egg; e. larva; f. pupa; g. instested stem; h. adult damage on leaf.

leaves along veins, leaving characteristic elongate incisions on either side of the midrib without much loss of lamina (Fig. 1b). Since the beetle does not defoliate the plants, growth of the new branches that emerge after the rains is not arrested.

Eggs are laid on internodal region of the mature stem. Tender branches and stem retaining even the slightest green color were avoided for egg laying. Probably this strategy ensures the survival of the young branches for the benefit of the herbivore.

Oviposition was observed during the evening hours. Females, usually seen on the leaves, descend along the stem upside down searching for branches suitable for oviposition. Once an appropriate site on a suitable branch is located, the beetle starts biting a hole on the bark by positioning itself upside down. The entire act of making oviposition hole takes more than 20 min. Sometimes it bites several smaller holes before settling down to bore the oviposition hole in which the egg is laid. While boring the hole, the antenna moves up and down in a characteristic fashion. The beetle after completing the oviposition hole assumes an upright position and inserts the apex of its abdomen into the hole on the bark. Of the two events of oviposition observed by us, the first beetle retracted its abdomen after seven minutes and again reinserted for three minutes and laid the egg. The second female retracted its abdomen after four minutes. A smaller puncture was observed on either side of the oviposition hole in all cases. In general, only single egg is laid in an internode and a branch may carry several eggs. Egg is cream yellow, 2.5 to 2.6 mm long and 0.7 mm wide, rod shaped, widest in the middle and is placed between the bark and the stem. Larva initially bores the stem in a spiral fashion outside the core area and later move into the stem. Larva is cream yellow, apodous, with brown head (Fig. 1c) and feeds actively for at least two to three months. Pupation occurs inside the burrow and the pupa is light yellow. Examination of infested stems of *Ixora* in the laboratory on 5th March 2007 revealed the presence of both larvae and pupae indicating a very brief pupal period after larval diapause. Adult emerges through a circular exit hole of about 3 mm diameter.

Presence of adults making incisions on leaves is the first indication of infestation. Yellowing of branches and exudation of frass and fibre through spiral shaped cracks on the bark around the stem is the initial symptom of attack. Infestation results in shredding of bark and death of thin branches but thicker stem withstands the damage. The plant puts forth newer branches in the ensuing season to make up the injury. The effect of the pest is comparable to that of hard pruning. Attacked plants, in general, did not die down completely; they survived the injury to act as host for several generations of the beetle, an evolutionary strategy that best serves the interest of the herbivore. During initial stages of infestation, plants often flowered profusely. This could probably be due to the damage to the vascular tissue that results in alteration of the C: N ratio. Though the pest does not kill the plant, its growth is severely curtailed due to destruction of branches resulting in loss of shape and appearance, making it less attractive.

Ixora chinensis Lam. with scarlet red flowers was the most favored host of *C. bicolor*. *Gardenia angusta* (L.) Merr. (Rubiaceae) with white flowers was equally susceptible. *Ixora finlaysoniana* Wallich with white flowers was comparatively less preferred. *Ixora* cultivar "Sunkist" grown as hedge plant was never found infested by *C. bicolor*. All the host plants reported here are introduced ornamental plants. Hence it is likely that there are other native host plants with which the beetle is originally associated. Apparently trophic selections of *C. bicolor* are limited to shrubs of Rubiaceae. This is the first report on the natural history and host plants of *C. bicolor*. The insect specimens will be deposited in the National Pusa Collection, Indian

Agricultural Research Institute, New Delhi and the Travancore Insect Collection, College of Agriculture, Vellayani. Plant vouchers (Accession Nos. 95942–95945) are deposited in the Calicut University Herbarium, Kerala.

ACKNOWLEDGEMENTS

We are indebted to Drs. H. V. Ghate, Modern College, Pune and C. Holzschuh, Austria for identification of the insect. Dr. A. K. Pradeep, Calicut University Herbarium identified the plants. Drs. HVG, P. Švácha and M. Barclay helped with literature. Dr K. D. Ghorpade critically reviewed the manuscript. KDP's work on beetles is supported by the Kerala State Council for Science, Technology and Environment, Trivandrum.

REFERENCES

Beeson C. F. C. and Bhatia B. M. (1939) On the biology of the Cerambycidae (Coleoptera). Indian Forest Records (New Series) Entomology, 5: 1–235.

Gahan C. J. (1901) A revision of *Astathes*, Newm., and allied Genera of Longicorn Coleoptera. Transactions of the Entomological Society of London (Part I), 37: 74.

Mathur R. N. and Singh B. (1960) A list of insect pests of forest plants in India and the adjacent countries (Arranged Alphabetically According to the Plant Genera and Species) For the use of Forest Officers. Part 6. List of insect pests of plant genera 'G' to 'K'. Indian Forest Bulletin (New Series). Entomology, 171(5: 1–99.

Nayar T. S., Beegam A. R., Mohanan N. and Rajkumar G. (2006) *Flowering Plants of Kerala — A Handbook*, Tropical Botanic Garden and Research Institute, Thiruvananthapuram, p. 1069.

Thomson J. (1864) Systema Cerambycidarum ou exposé de tous les genres compris dans la famille des cérambycides et familles limitrophes. Mémoires of the Societe Royale des Sciences de Liège, 19: 1–540.

(Received 23 June 2009; accepted 15 August 2009)

ENTOMON 34(3): 205–206 (2010)
Short Communication No. ent.34313

New record of *Chrysocoris purpureus* (Westwood) and *C. marginellus* (Westwood) (Hemiptera: Scutelleridae) on *Emblica officinalis* Gaertn from India

M. Shanthi*, D. S. Rajavel, R. K. M. Baskaran and R. Nalini

Department of Agricultural Entomology, Agricultural College and Research Institute, Madurai 625 104, Tamil Nadu, India
Email: cshanthiento07@gmail.com

ABSTRACT: Three species of scutellerids, *Chrysocoris purpureus* (Westwood), *C. marginellus* (Westwood) and *Scutellera nobilis* Fab. were recorded on *Emblica officinalis* Gaertn during a survey. The two *Chrysocoris* species are new records on this plant from India.

KEYWORDS: new record, *Chrysocoris purpureus*, *Chrysocoris marginellus*, *Emblica officinalis*

Aonla, *Emblica officinalis* Gaertn. (Euphorbiaceae), is one of the important fruit trees with medicinal value. It is cultivated in large area and is infested by a number of insect pests (Haseeb, 2005). Survey of insect pests on aonla at Agricultural College and Research Institute, Madurai, Tamil Nadu, India, from 2006 to 2007 revealed three species of scutellerids *viz.*, *Chrysocoris purpureus* (Westwood), *C. marginellus* (Westwood) and *Scutellera nobilis* Fab. (Hemiptera: Scutelleridae). *C. purpureus* and *C. marginellus* are first records on *E. officinalis* from India. Earlier, only two scutellerids, *Scutella nobilis* (Kulkarny, 1967; Meshram and Garg, 1999; Haseeb, 2005) and *Chrysocoris grandis* (Thunberg) (Kulkarny, 1967) were recorded on aonla.

However, *C. purpureus* was earlier reported on *Jatropha curcas* Linn. in South India (Kershaw and Kirkaldy, 1908; Chitra and Dhyani, 2006; Manoharan *et al.*, 2006; Ambika *et al.*, 2007). Kumar (1965) reported *C. purpureus* as a colour morph of *C. stollii* (Wolff). *C. stollii* also occurs on citrus in Assam; *Litchi chinensis* Sonn. in Bihar (Nair, 1975; Butani, 1979), *Croton sparsiflorus* Morong, *Clerodendron infortunatum* Gaertn. (Nayar et al., 1981), *Costus speciosus* Smith. and *Adathoda vasica* Nees. (Regupathy *et al.*, 2003). There are no reports on the status of *C. marginellus* in India.

*Corresponding author

Adults of *C. purpureus* are stout, shiny bluish green, with five spots on the pronotum in two rows and seven spots on scutellum. The incidence was found throughout the year except during May and June. Ten to sixteen adults per tree were found during October to November following North East monsoon showers. Adults of *C. marginellus*, with eleven spots on pronotum and eight spots on scutellum, were observed only during October (3 to 6 nos./tree). *C. marginellus* adults are stout but smaller than *C. purpureus*.

ACKNOWLEDGEMENTS

We are highly thankful to Dr. C.A. Viraktamath, Emeritus Professor (Entomology), GKVK, University of Agricultural Sciences, Bangalore and Dr. K.D. Prathapan, Associate Professor (Entomology), College of Agriculture, Vellayani, Trivandrum, Kerala for identification of the scutellerid bugs. The specimens were deposited in taxonomic collections of GKVK, University of Agricultural Sciences, Bangalore.

REFERENCES

Ambika S., Manoharan T., Stanley J. and Preetha G. (2007) Scutellerid pests of Jatropha and their management. Annals of Plant Protection Sciences, 15(2): 370–375.

Butani D. K. (1979) *Insects and Fruits*, International Book Distributors, Dehradun, p. 374.

Chitra S. and Dhyani S. K. (2006) Insect pests of *Jatropha curcas* L. and the potential for their management. Current Science, 91: 162–163.

Haseeb M. (2005) Insect pests of amla and their management. In: *Amla in India*, Mehta S. S. and Singh H. P. (Eds). Aonla Growers Association, Salem, 128–139.

Kershaw J. C. and Kirkaldy G. W. (1908) *Transactions of the Entomological Society*, London, 59–62.

Kulkarny H. L. (1967) *General Entomology for Agricultural Students*, Asia Publishing House, New Delhi, 216 pp..

Kumar R. (1965) Contributions to the morphology and relationships of Pentatomidae (Hemiptera: Heteroptera) Part I. Scutelleridae. Australian Journal of Entomology, 4(1): 41–55.

Meshram P. B. and Garg V. K. (1999) A report on the occurrence of *Scutellera nobilis* Fab. on *Emblica officinalis* Gaertn. Indian Forester, 125(5): 536.

Manoharan T., Ambika S., Natarajan N. and Senguttuvan K. (2006) Emerging pest status of *Jatropha curcas* (L.) in South India. Indian Journal of Agroforestry, 8: 66–79.

Nair M. R. G. K. (1975) *Insects and Mites of Crops in India*, ICAR Publications, New Delhi, p. 408.

Nayar K. K., Ananthakrishnan T. N. and David B. V. (1981) *General and Applied Entomology*, Tata McGraw Hill Publishing Company Ltd., New Delhi, pp. 178.

Regupathy A., Palanisamy S., Chandramohan N and Gunathilagaraj K. (2003) *A Guide on Crop Pests*, Sheeba Printers, Coimbatore, pp. 276.

(Received 26 March 2009; accepted 15 August 2009)

GUIDELINES TO AUTHORS

Scope: ENTOMON will publish original research papers on insects, arachnids and myriapods. Reviews are not acceptable.

Papers on morphology, anatomy and histology will be considered only when they form part of systematics, physiology or behavioural studies.

Announcements of seminars/symposia, book reviews and other items of entomological interest will also be considered for publication.

Types of papers: Articles up to 3 printed pages in length (1800 words) will be published as **short communications** and those between 4 and 10 pages (up to 6000 words) as **full papers**.

Full paper should be organized under the following sub-heads—Abstract, Introduction, Materials and Methods, Results, Discussion, Acknowledgements and References.

Short communication should be organized in the same way, but without the subheadings.

Publication policy: Manuscripts submitted for publication in ENTOMON should not have been published or submitted for publication elsewhere.

At least one of the authors should be a member of AAE.

Page charges are applicable at the rate of Rs. 100 per printed page for authors in India and US $ 10 for authors overseas. Invoice will be sent to the authors along with the galley proof.

Twenty five **reprints** of the paper will be supplied free of cost to the authors.

Typing and submission: Manuscripts should be typed double space on one side of good quality paper, having 3.5 cm left margin and 2.5 cm right margin.

The first page should contain the title, author's name affiliation and e-mail address. When the number of authors is more than one, indicate the name of the corresponding author with an asterisk and specify 'Corresponding author' in a footnote. The second page should contain the abstract, followed by key words and a running title. From page 3 onwards, type the text continuously from Introduction to References. Place the tables on separate sheets at the end of the paper. The pages should be numbered.

Three copies of the manuscript, complete in all respects including illustrations, should be sent to the Managing Editor, ENTOMON, Department of Zoology, University of Kerala, Kariavattom P.O., Thiruvananthapuram 695 581, Kerala, India.

An electronic version need be sent only after acceptance of the paper for publication.

Guide for writing: Careful attention to the following guide will facilitate early acceptance of your paper for publication in ENTOMON. Although some of these suggestions may appear trivial, they have been prompted by our experience in reviewing the papers received for publication. Keep in mind that ENTOMON is a research journal and your paper will be read only by those who are specialists in the respective fields of research.

Title should be brief and should reflect the specific content of the research reported in the paper.

Abstract should be informative, not indicative. It should very briefly highlight the aim of the study and major conclusions. Normally it should not exceed 150 words.

Key words should be limited to four or five most pertinent indicators of the work, relevant to indexing the article.

Introduction should be brief, normally not exceeding 300 words. Include the specific aim of the research, a review of the available information in the area and existing gap in knowledge. The introduction should thus justify the work carried out. Avoid elementary details and repetition of well known facts. For example, in a paper reporting the efficacy of a biopesticide against a particular pest, it is not necessary to explain the hazards of chemical pesticides, alternative methods of insect control and advantage of integrated pest management. Limit the literature review to what is most relevant to the topic under study.

Materials and Methods should provide just enough details to permit proper interpretation of the results. Materials used need not be described separately if it is evident from the methods given. Technical description of the method is needed only when the method is new. If the method followed has been already described elsewhere, just give the reference. If any alteration is made, describe the alteration alone, with reason.

Results: Adequate care should be taken to organize and present the results in a clear, concise and summarized form.

Quantitative data should always be analysed using suitable statistical methods. Organize the data into well planned tables. Each table should be self-explanatory.

Do not repeat the data presented in the table in the text. Quote the relevant figures in the text only when it is essential for highlighting some particular finding.

Due care should be taken while interpreting the results of statistical analysis. For example, treatments which show higher numerical value cannot be treated as superior to those having lower numerical values when there is no statistically significant difference.

Interpretation of the data should be with reference to the objectives set in the experiment.

Do not include graphs duplicating the data presented in the tables.

When the research involves repetition of the work already reported by others, include the new findings alone in the paper.

Illustrations included in the paper should be essential for explaining some points in the text. Photographs of the life stages of an insect are not useful unless the insect is being reported for the first time. Illustration should be of good quality. Limit the number of photographs to 4–6 and organize them into plates wherever possible. The illustrations should be numbered consecutively as Fig. 1, Fig. 2, etc., without distinction between drawings, graphs and photographs. Labelling should be legible and large enough to stand suitable reduction. Legend for the figures should be typed on a separate page. All figures must be referred to, at appropriate places, in the text.

The cost of printing colour illustration is to be met by the author.

Discussion: The discussion section is intended to critically analyse and interpret the results with reference to the objectives set forth in the study. It should highlight the importance of the results in relation to what is already known. It should also point out the limitations of the study, if any. The discussion should not repeat details given under Results, except to highlight some conclusions.

References should list all publications cited in the text, in alphabetical order. Do not include any references not cited in the text. Some authors show a tendency to cite too many references in support of a statement. Cite only a few references most pertinent to the point dealt with. Follow the citation style given below.

Examples of citations in text:

Krishnaswamy (1978, 1979)

Govindan *et al.*(1998)

(Reddy, 1978; David, 1991)

Examples of citations under References:

Articles in Journals:

Nayar K. K. (1953) Neurosecretion in *Iphita*. Current Science, 22(2): 149.

Nair M. R. G. K. and Mohandas N. (1962) On the biology and control of *Carvalhoeia arecae*, a pest of areca palms in Kerala. Indian Journal of Entomology, 24: 86–93.

Jalaja M., Muraleedharan D. and Prabhu V. K. K. (1973) Effect of extirpation of median neurosecretory cells on reproduction in the female red cotton bug, *Dysdercus cingulatus*. Journal of Insect Physiology, 19(1): 29–36.

Books and Articles in Books:

Novak V. J. A. (1966) *Insect Hormones*, Methuen and Co., 478 pp.

Wigglesworth V. B. (1964) The hormonal regulation of growth and reproduction in insects. In: *Advances in Insect Physiology*, vol. 2 (Eds. Beament J. W. L., Treherne J. E. and Wigglesworth V. B), Academic Press, London, pp 247–335.

Review Procedure: Manuscripts will be subjected to a preliminary scrutiny by an Editorial team and those conforming to the general guidelines set above will be referred to experts for detailed review; others will be returned to the author for resubmission in the prescribed format. Based on detailed review, the corresponding author will be advised of acceptance, non-acceptance or need for revision. The revised

manuscript will be scrutinized again by an Editorial team (and by expert referees, if needed) before final acceptance. On final acceptance, the author will be asked to submit an electronic version of the manuscript. Proof will be sent to the corresponding author. It should be checked and returned within three days of receipt. The journal reserves the right to proceed with publication if corrections are not communicated promptly.

Strict conformity with the above guidelines will ensure speedy publication of your paper.

AUTHOR INDEX

Reg. No. 123SBN

Edited, printed and published by D. Muraleedharan for and on behalf of Association for Advancement of Entomology, CABB, University of Kerala, Trivandrum. Typeset in TEX by River Valley Technologies, Trivandrum. Printed at St. Joseph's Press, Trivandrum